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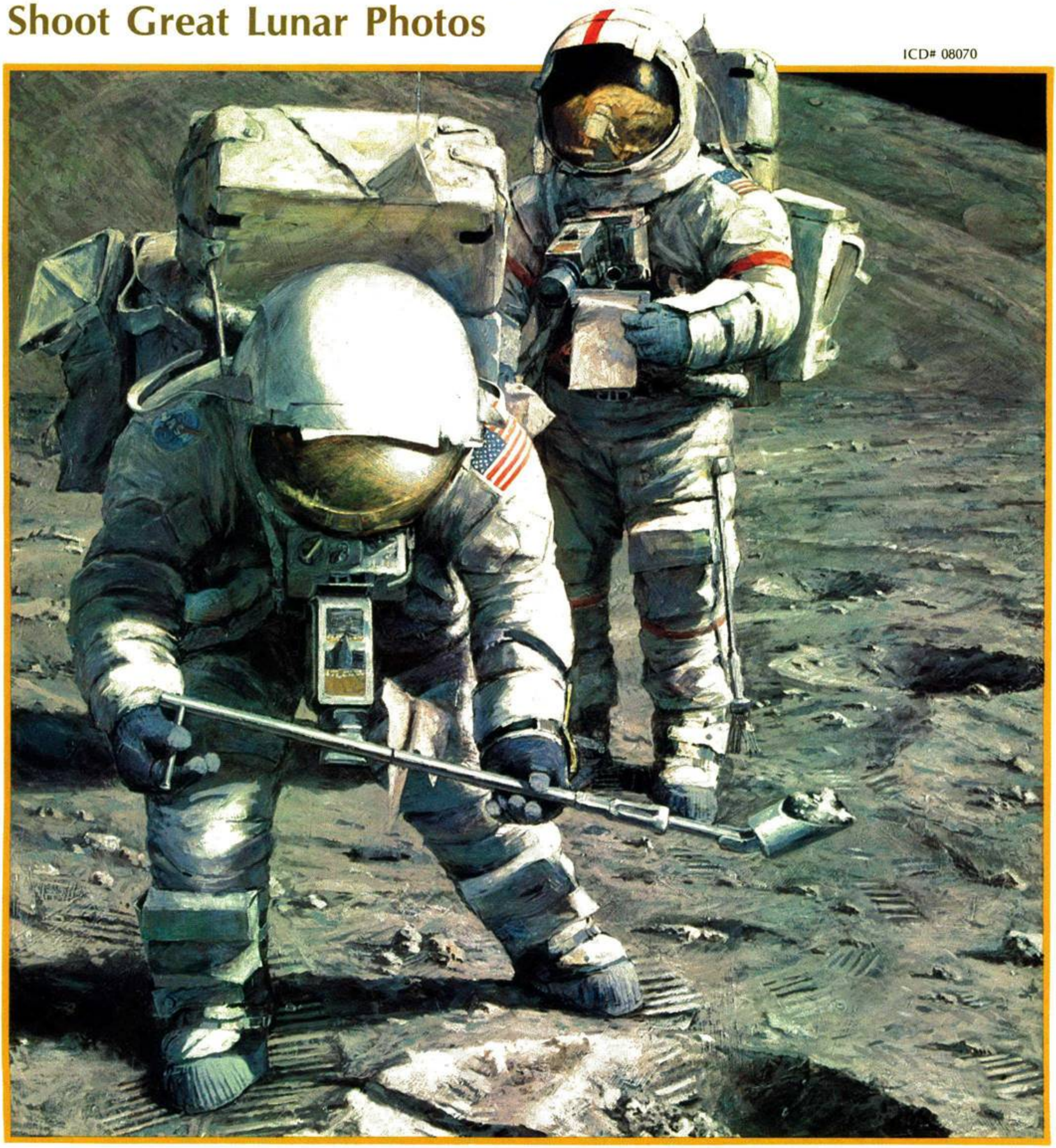

The Fate of the Moon Rocks

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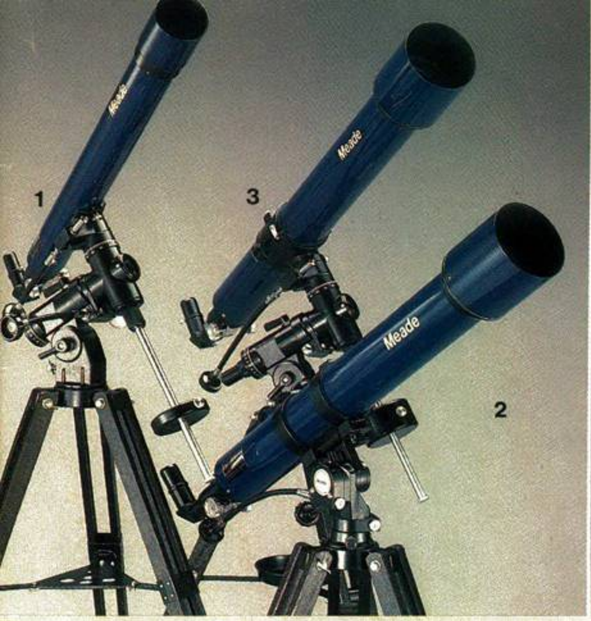

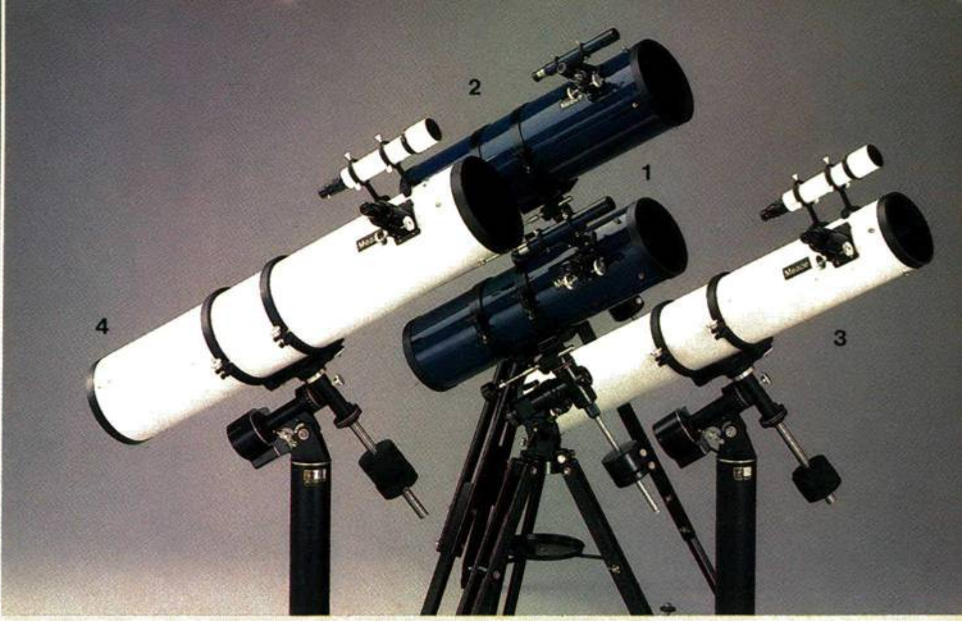

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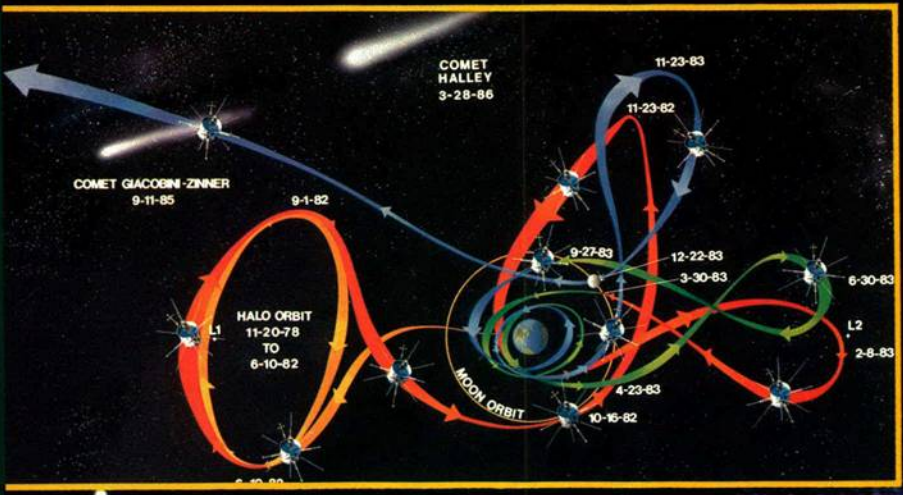
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12-22-83
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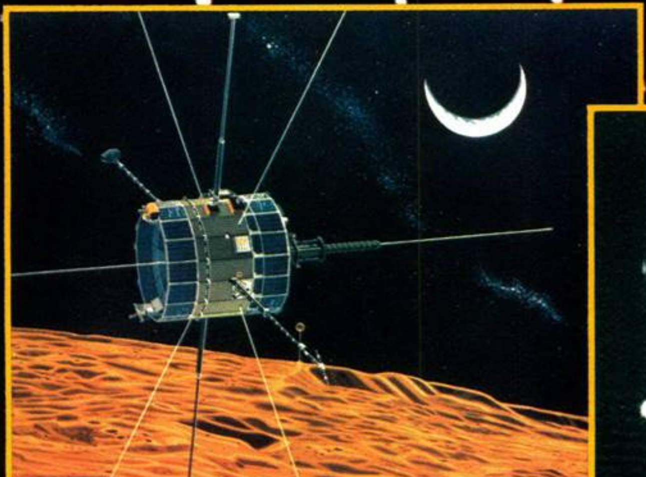
MOON ORBIT

NASA

Comet G-Z, July 26, 1985, courtesy Uwe Fink, University of Arizona



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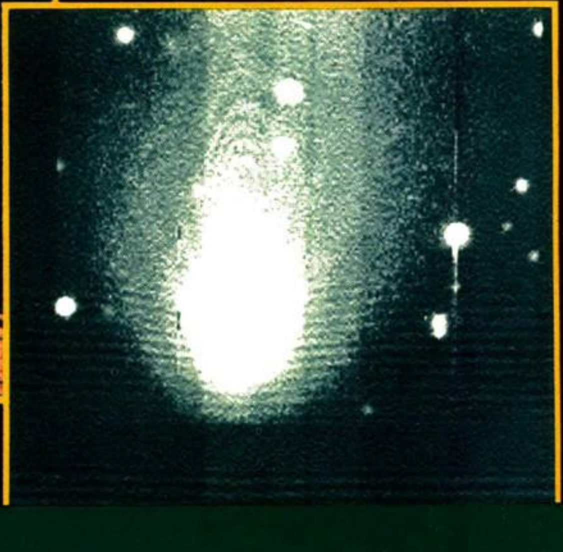
Comet G-Z, Sept. 11, 1985,
from Kitt Peak National Observatory



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Cover: Apollo 17 astronaut Harrison Schmidt nabs a soil sample as Gene Cernan looks on. This month, ASTRONOMY looks back on what we've learned from the lunar samples — and what we haven't. Painting by Apollo 12 astronaut Alan Bean. These pages: The International Cometary Explorer mission took the long way 'round to reach Comet Giacobini-Zinner. Our story begins on page 6.

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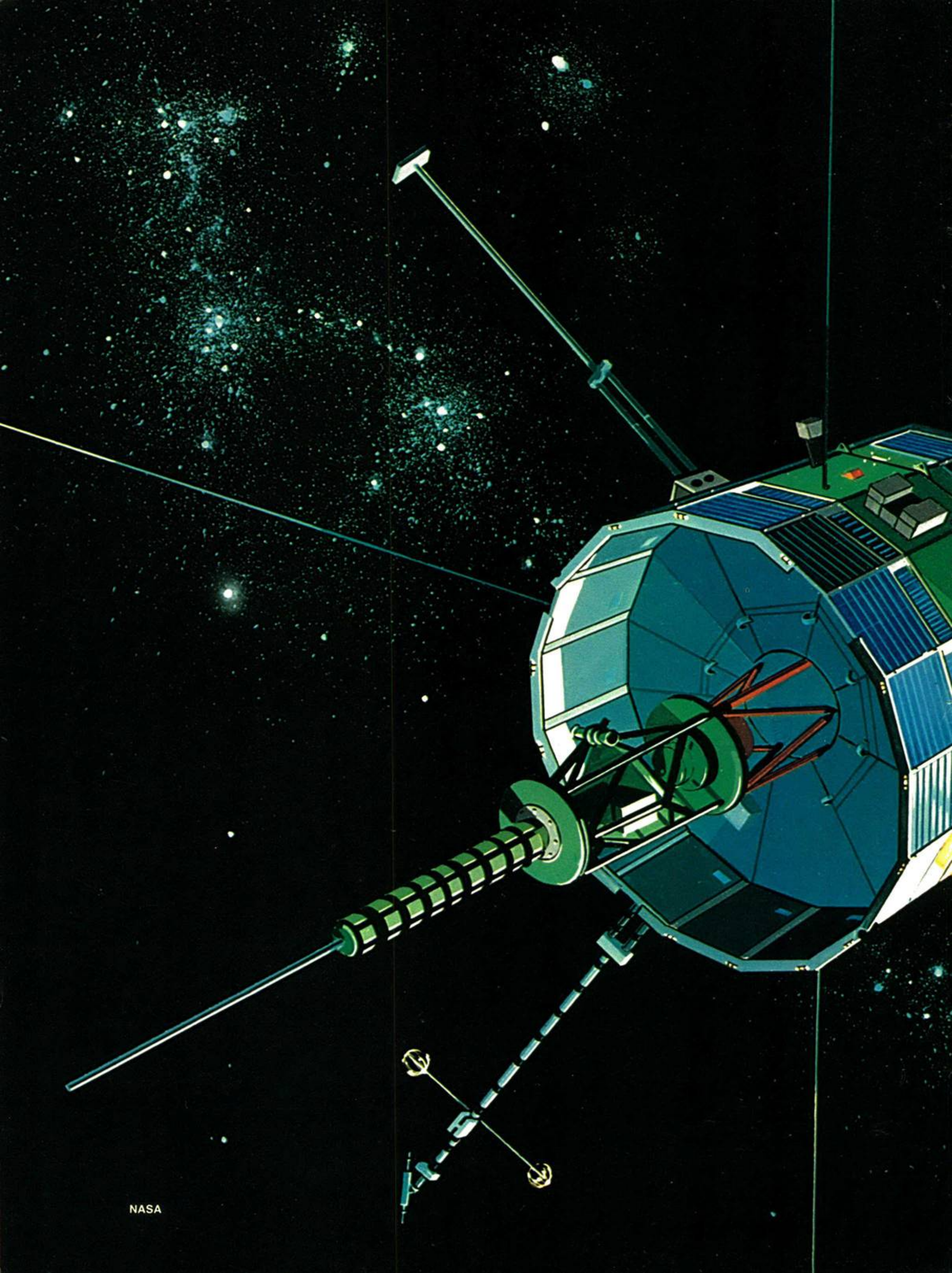

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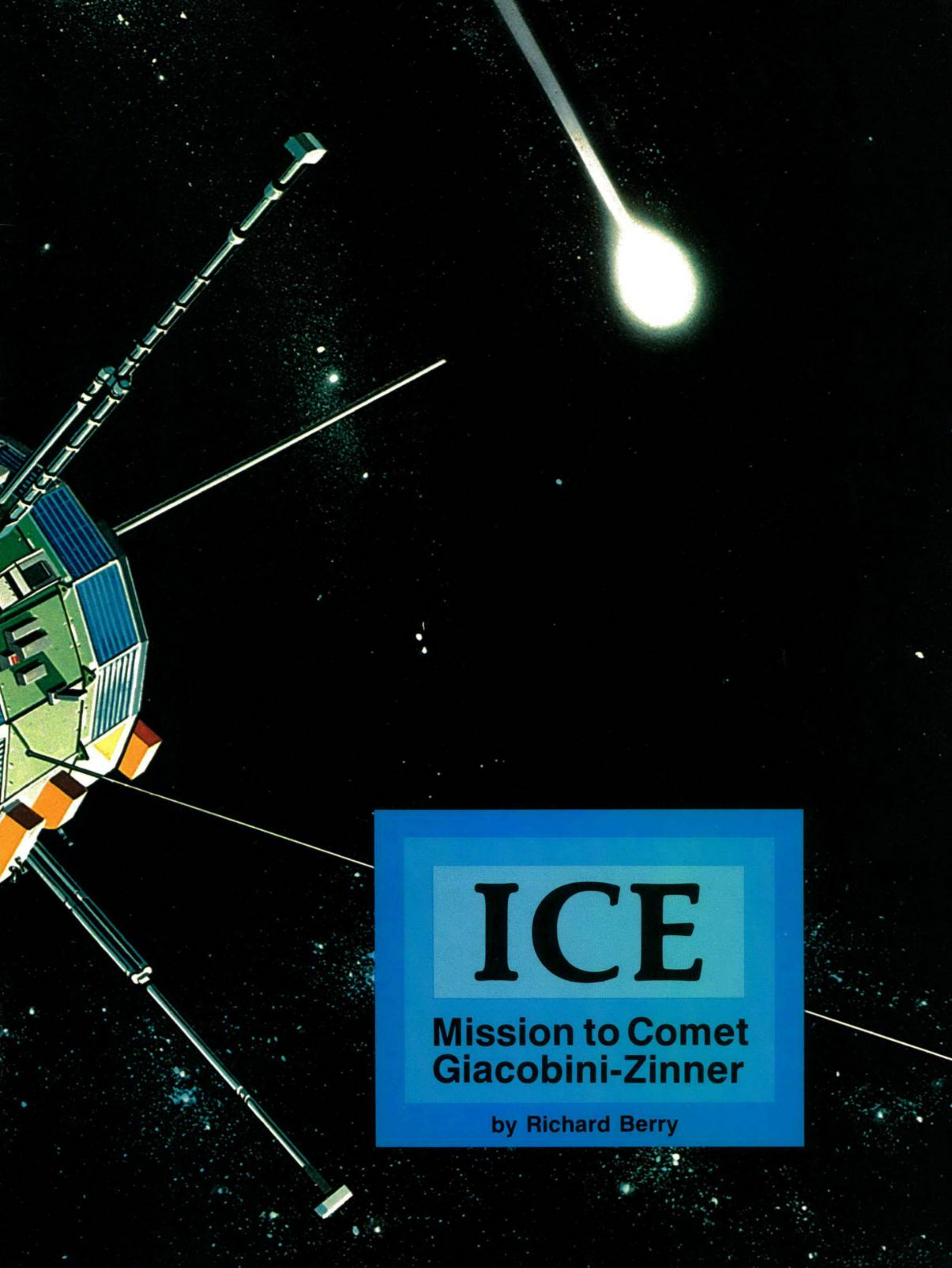
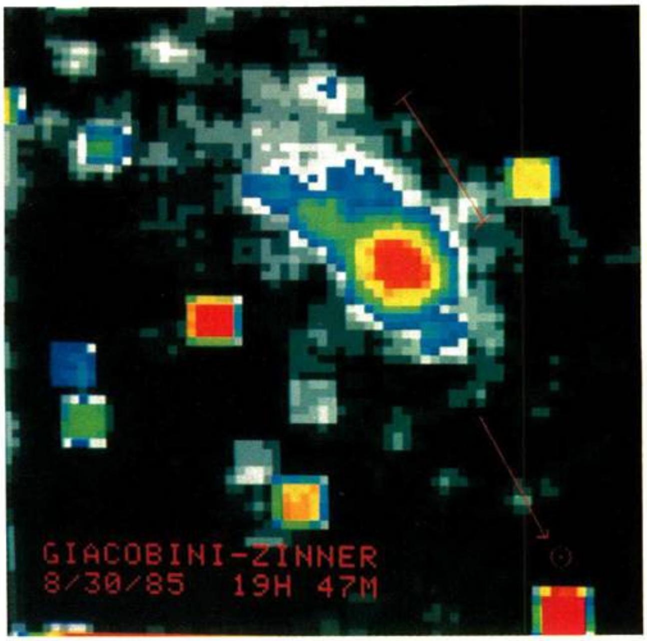


ICE

Mission to Comet Giacobini-Zinner

by Richard Berry



Left: The International Ultraviolet Explorer (IUE) telescope photographed Comet Giacobini-Zinner from Earth orbit, then radioed the image to Earth for digital processing. The IUE also measured the comet's gas production rate. Right: Four orbits ago, in 1959, Elizabeth Roemer photographed G-Z showing a long, slender ion tail at the U.S. Naval Observatory in Flagstaff, Arizona. NASA photos.

On September 11, 1985, the International Cometary Explorer, or ICE, became the first human artifact to fly through a comet. It was midnight at mission control when instruments aboard ICE detected the unmistakable signature of the comet: a spray of energetic electrons from the plasma surrounding it. After seven years of watching the spacecraft cruising the fitful blasts of solar wind and exploring the reaches of Earth's slender magnetotail, the engineers and astronomers on Earth grinned. Comet Giacobini-Zinner lay just ahead: ICE had made it!

As the spacecraft bore down on the comet at 21 kilometers per second, the instruments detected bursts of electrons more and more frequently. Then, around 5:40 a.m. Eastern Daylight Time, the magnetic field fitfully rose from a strength of 8 gammas, characteristic of interplanetary space, to 40 gammas over a period of some 15 minutes. Simultaneously, other instruments reported that the spacecraft was now bathed in a sea of energetic electrons moving violently in all directions. Although it had entered a region of space controlled by the comet, ICE still lay 188,000 kilometers from the tiny nucleus.

ICE was not originally a comet mission. It became one after spending four years traveling between the Sun and Earth and two more years flying "downwind" of Earth in its geotail. ICE was an impostor, its mission an improvisation, its spacecraft a surrogate for NASA's never-funded mission to Comet Halley. Yet the scientists were happy: ICE was a good mission despite its dubious origin.

The instruments aboard the spacecraft that had antennas spanning 100 yards complemented the European, Russian, and Japanese missions to Halley by providing valuable data on a different comet. Besides, ICE had reached Comet Giacobini-Zinner six months before any of the other spacecraft would reach Halley. The scientists' greatest worry — not even a worry for many of them — lay in possible effects of cometary dust impacting at 21 kilometers per second. This might clip off an antenna, sandblast the spacecraft structure, or coat and cut the efficiency of the solar cells supplying electrical power to the spacecraft.

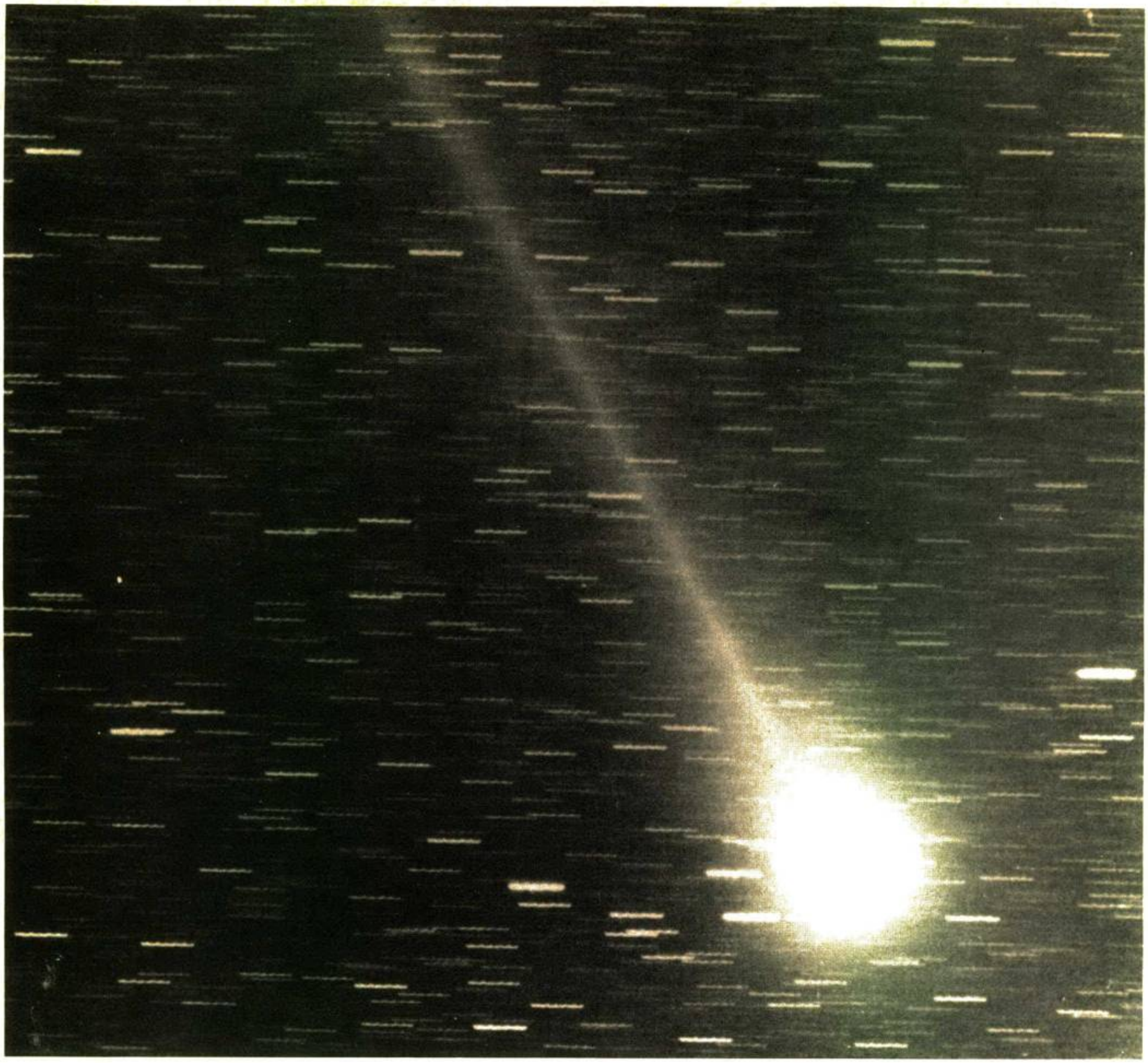
As it nosed deeper and deeper into Comet Giacobini-Zinner's envelope of subatomic particles and fields, ICE radioed instrument readings back to Earth, four light-minutes distant. A blind spacecraft, ICE carried no cameras to photograph its surroundings. It had been built to "feel" magnetic fields, to "smell" the protons and electrons, to "taste" the ions, and to "hear" radio waves over a broad range of energies, wavelengths, and temperatures. ICE's original purpose was to explore the phenomena of the outflowing solar wind and its interactions with planetary magnetospheres. Once the spacecraft's primary and secondary missions were completed, its name was changed from International Sun-Earth Explorer 3 (ISEE-3) to International Cometary Explorer. ICE was now carrying out a mission barely dreamt of at the time of its launch.

As the spacecraft sped toward an aim point 7,800 kilometers directly behind the comet's nucleus, the turbulence died away. The energies of the protons and the temperature of the electrons rose higher than the instruments aboard ICE had ever measured before. Then, abruptly, at 6:50 a.m., ICE entered the comet's tail. A hundred times denser than the solar wind, permeated by an orderly magnetic field, and made up of heavy ions (mostly water molecules missing one electron), the tail was so distinct that the astronomers and engineers immediately knew that's where they were. They found dust in the tail, too. Every second or so, ICE's plasma-wave radio receiver registered the impact of a cometary dust particle on its antennas. But even the densest and dustiest regions of the tail produced no detectable drop in the electric power output of the spacecraft's solar panels.

Mission scientists were particularly interested in one feature of the tail: if the current accepted comet theories were correct, it would contain two lobes with opposite polarity, separated by a region with no magnetic field. Upon entering the tail, ICE's magnetometer reported a magnetic field of 20 gammas to the watchers on Earth. As the spacecraft crossed the central axis of the tail at 7:02, the field abruptly disappeared and then reappeared with the opposite polarity. The scientists again smiled: the distant spacecraft had just confirmed a cometary feature that had been, until then, only conjectural. At 7:10 a.m., 20 minutes after entry, ICE exited the tail — intact.

A few minutes later, ICE was again bathed in an energetic electron plasma. A little over an hour later, at 8:22, ICE re-entered interplanetary space, the domain of the solar wind. Back on Earth, relaxing a bit and looking over their printouts, the scientists were pleased with the data ICE had transmitted back to Earth during its 200,000-kilometer-long traverse of the comet.

But some aspects of the data puzzled them. For one thing, the boundary between the solar wind and the comet magnetosphere had not been abrupt as are the magnetosphere boundaries of Earth, Mars, Jupiter, and Saturn. Rather, the transition spread out over 15 minutes. What was different about this comet? And to their relief — or at least to the relief of those scientists who had feared that cometary dust might be a problem — dust had not destroyed ICE. Indeed, it had hardly affected the spacecraft at all! Most interesting of all, the cometary environment



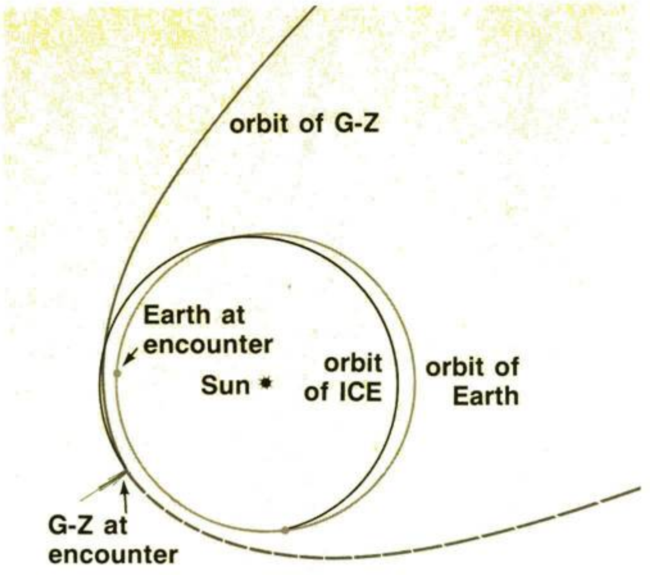
had turned out to be unexpectedly turbulent, more complex, and considerably more energetic than the scientists had anticipated. ICE had yielded a rich scientific harvest of data.

The ICE mission to Comet Giacobini-Zinner was the culmination of a seven-year-long journey through space and the result of scientific opportunism that was carried out by an unprecedented display of orbital acrobatics. ICE began life as ISEE-3, the third of three spacecraft built to monitor the solar wind, explore Earth's magnetosphere, and study the interaction between them. ISEE-3 was to be stationed in a halo orbit 1.5 million kilometers sunward of Earth to measure the unperturbed outflow of solar wind before it reached our planet's magnetic field. Its data were to be compared with data from other spacecraft inside the magnetosphere. Because many small maneuvers were required to keep the spacecraft on station, it had been fitted with 12 four-pound thrusters and an ample supply of hydrazine fuel.

The mission began in August 1978, as the 1,034-pound spacecraft roared aloft atop a Thor Delta rocket; it passed the Moon's orbit three days after launch. ISEE-3 attained halo orbit, its first goal, 100 days after launch — and there it stayed from November 1978 until June 1982. At that time, a more important mission was proposed for ISEE-3: to fly down Earth's geomagnetic tail and investigate the down-tail effects of magnetic storms. With a small maneuver on June 10, 1982, ISEE-3 left its halo orbit and swung past Earth at a range of 400,000 km that October. By December, acting under the combined gravitational attractions of the Sun and Earth, ICE headed back toward Earth for a close swingby that would direct it down the geotail.

Yet even as ISEE-3 was carrying out its second assignment, NASA's mission planners were developing more ambitious plans for it. Following their failure to obtain approval of a sophisticated (and expensive) mission to Comet Halley, NASA astronomers were looking for a low-cost spacecraft to fly to a comet — and ISSE-3 was available.

Although it lacked the cameras and dust-detectors necessary for a complete comet mission, ISEE-3 did satisfy one primary comet mission objective: it could probe the interaction between a comet and the solar wind. And,



Left: After leaving the Earth-Moon system, ICE orbited the Sun in a slightly elliptical orbit which, a year and nine months later, intercepted the orbit of Comet Giacobini-Zinner. The comet's orbit is inclined some 30° relative to the page; a dotted line indicates when it lies south of the ecliptic. Right: ICE's path through the comet. Closest approach occurred at 7:02 a.m. EDT.

although they weren't designed for it, several of the experiments *could* be made to detect impacting dust particles. At a cost of $3 million, ICE was truly a bargain-basement space mission. Furthermore, a perfect target was available — Comet Giacobini-Zinner — which ISEE-3 could reach six months before any other spacecraft would reach Comet Halley. Thus, on February 8, 1983, ISEE-3 performed a small manuever that lined it up for a critical gravity-assist flyby of the Moon.

At launch, the 16-sided half-ton spacecraft stood a mere 63 inches high and 68 inches across its flat solar-cell-studded sides. At one end, a tower held the Earth-link antennas and science instruments lay along the spacecraft's "equator." In deep space, spinning at 20 revolutions per minute, ISEE-3 unfurled four rigid instrument booms and eight radio-science antennas. The spacecraft's spin served to stabilize it, much like a gyroscope. One boom served to isolate the sensitive magnetometer from stray magnetic fields generated by the spacecraft itself. Four radio antennae projected 46 feet along the spin axis of the spacecraft and four others spanned 302 feet radially. The solar cells formed two bands around ISEE-3; at launch they would provide 182 watts of electrical power to the engineering and science instruments aboard.

For a year after its first lunar encounter, ISEE-3 rode the gravitational fields of the Earth, the Moon, and the Sun in a daring game of celestial billiards, gaining and losing energy in four subsequent lunar swingbys, firing its tiny thrusters at seven critical junctures. Then, on December 22, 1983, the spacecraft swung within 120 kilometers of the lunar surface and shot out of the Earth-Moon system into solar orbit, bound for Comet Giacobini-Zinner.

Comet Giacobini-Zinner — G-Z, for short — is a moderate-sized comet with an orbital period of 6.5 years. The comet acquired its name from Michel Giacobini, who discovered it at Nice Observatory in 1900, and Ernst Zinner, who rediscovered it 13 years later from the Remeis Observatory, in Bamberg, Germany. Since its discovery, G-Z has been observed on eleven apparitions; it reached perihelion on September 5, 1985. The comet has proven itself one of the brighter and more active short-period comets, subject to sporadic brightenings.

Because comet nuclei throw off jets of gas and dust, they alter their own orbits. Celestial mechanicians (i.e., astronomers who compute orbits) call these rocket-like effects non-gravitational forces. From the time of its discovery until 1959, non-gravitational forces altered G-Z's orbit in a fairly regular fashion at every apparition. But something happened between 1959 and 1965. When G-Z returned in 1965, the non-gravitational forces acted in the opposite direction, suggesting that the nucleus was now rotating opposite its previous direction. According to one study, the nucleus is approximately 2.5 kilometers in diameter and seems to be rotating rapidly, which means it may break up. All told, G-Z is an active and interesting object — a fine candidate for a comet mission.

G-Z's orbit, too, scores high with mission planners. Although it is inclined 32° to the ecliptic, G-Z reaches perihelion just 1.028 astronomical units from the Sun, slightly beyond Earth's orbit. Furthermore, its perihelion occurs just above the ecliptic plane. G-Z is an easy comet to reach when it's closest to the Sun — when it's brightest and most active. Even a spacecraft with small hydrazine thrusters — like ICE's — could fly out to meet Comet G-Z.

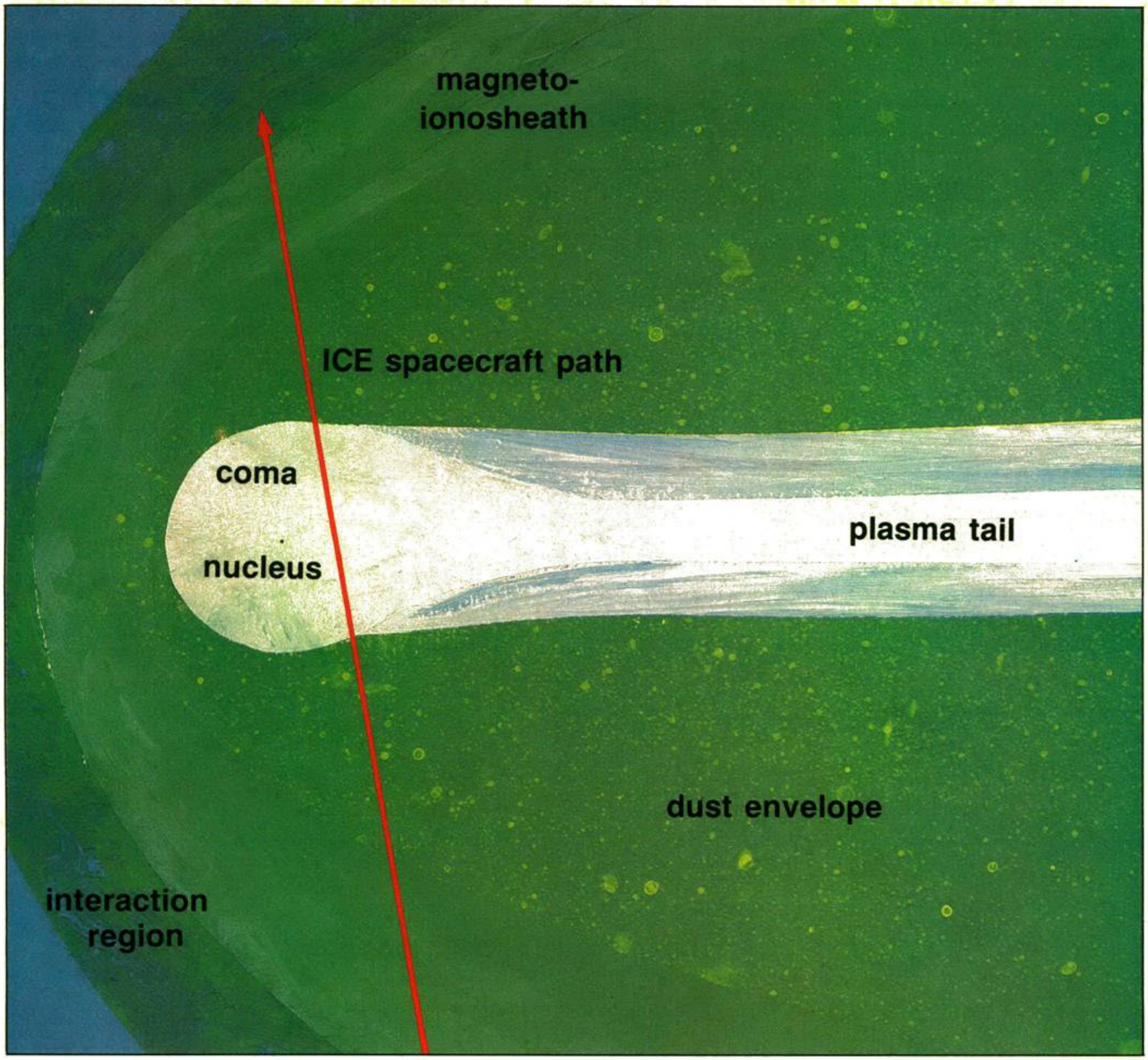
And that's what ICE did.

Two days after the spacecraft's fly-through — too soon for definitive analysis — mission scientists delivered their first report on the encounter. The mission had been a complete success. ICE had done its job, and done it well. Furthermore, as comet expert John Brandt put it: "In a very broad sense, our picture [of cometary behavior] was confirmed," especially in regions close to the plasma tail. Brandt said ICE confirmed — by direct measurement — that water molecules are the most abundant species given off by the cometary nucleus.

Brandt and the principal investigators for the various instruments were somewhat surprised that particles and magnetic fields didn't pile up (in a "bow shock") ahead of the comet. Another surprise was the high flux of energetic heavy ions of cometary origin trapped in the solar wind — the region farthest from the well-studied visible parts of the comet.

The astronomers' picture of a comet is fundamentally quite simple; its complexity lies in the ramifications of simple principles. A comet is the interaction between a small icy body, called the comet nucleus, and our Sun. These bodies, typically only a few kilometers in diameter, are made of ordinary water ice (roughly 85%), and a mix of other frozen materials (ices of carbon monoxide, methane, and ammonia), fine dust, and possibly rock-sized objects. Presumably formed at the same time as the solar system, comet nuclei have remained in cold storage in the depths of space for billions of years, frozen samples of the primordial "stuff" that went into forming the outer planets. These objects reach the solar vicinity as a result of tiny gravitational nudges from passing stars.

As a comet's orbit brings it toward the Sun, the nucleus feels the effects. Most obvious, of course, is sunlight, which warms the object. The Sun also emits ultraviolet radiation. Ultraviolet radiation reaching Earth's surface gives people sunburn; in space, ultraviolet light can drive one or more electrons off an atom or molecule.



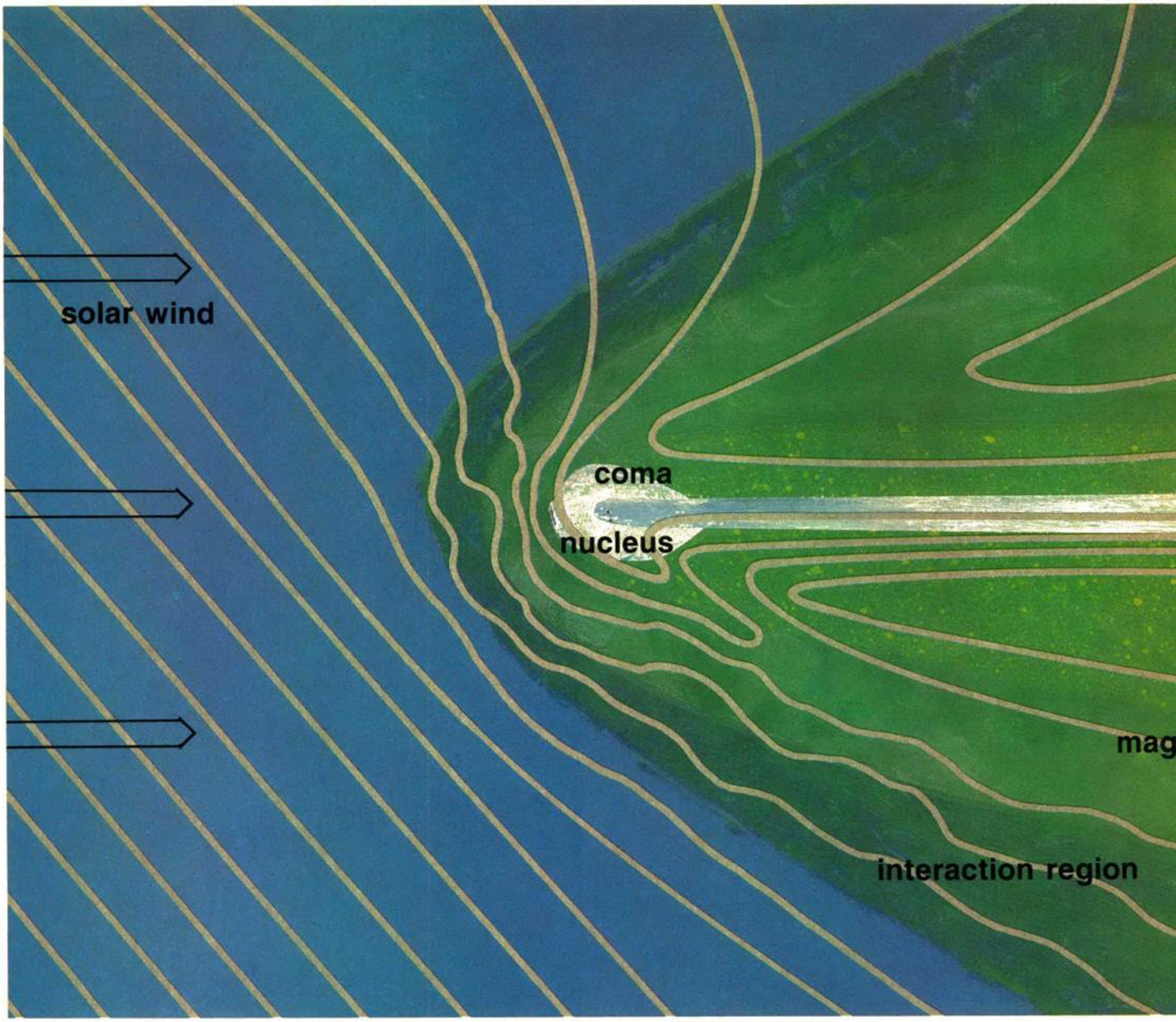
Tom Hunt

The process of losing an electron is called ionization. An atom or molecule that has lost an electron is called an ion. (We will have more to say about ions later.)

The Sun also gives off a flow of charged subatomic particles called the solar wind. The protons and electrons that make up the bulk of the solar wind stream outward from the Sun at roughly 400 kilometers per second. Embedded in the solar wind is a magnetic field made up of bits of the solar magnetic field carried off by the solar wind. The magnetic field is extremely important because ions that are missing one or more electrons carry an electric charge and therefore cannot move across magnetic field lines easily. This means that the particles of the solar wind are locked into the magnetic field; it also means that the magnetic field in the solar wind sweeps up any ions that it encounters in interplanetary space.

When small rocky bodies — asteroids — approach the Sun, they warm up but nothing much happens. Everything volatile soon gets baked out of the surface rocks, leaving the rocky body essentially inert. But when a comet nucleus swings within 2.5 astronomical units of the Sun, it becomes a comet. As the icy surface materials warm up, the constituent molecules vibrate faster and faster until they are moving fast enough to escape the surface. This process is called sublimation. Massive objects such as planets have enough gravitational pull to retain, as an atmosphere, molecules that would escape from a smaller body. With an escape velocity of 0.7 meters per second, a comet nucleus does not have enough gravity to retain molecules, so they simply fly off into space. A water molecule typically sublimates at 300 meters per second.

At perihelion during this apparition, G-Z lost around 5×10^{28} molecules *per second*. This measurement, made from Earth orbit by the International Ultraviolet Explorer (IUE) spacecraft, is about one-fifth the predicted gas production rate of Comet Halley (a large comet), and six times that of Comet Encke (a small comet). Thus, a moderate-sized comet throws something like 1.5 tons of water and carbon monoxide per second into the interplanetary medium. Surprisingly, this depletes the comet's icy crust by only an inch or two per day, resulting in a net loss of several meters of ice at each return. (G-Z's "annual" loss is comparable to the spring snow-melt in,



for example, southeastern Wisconsin.) Assuming a nuclear diameter of one kilometer, G-Z should be good for several hundred more returns before it peters out.

When near the Sun, a comet loses its icy surface material as fast as the Sun can supply the energy necessary to evaporate it. As the frozen matrix of water, carbon dioxide, methane, and ammonia sublimes into space, dust particles embedded in the comet since its formation float free and are wafted into space by the outward flow of gas from the comet. Typical dust particles are a micrometer in diameter, roughly the same size as particles in cigarette smoke, but they may be larger — even rock-sized.

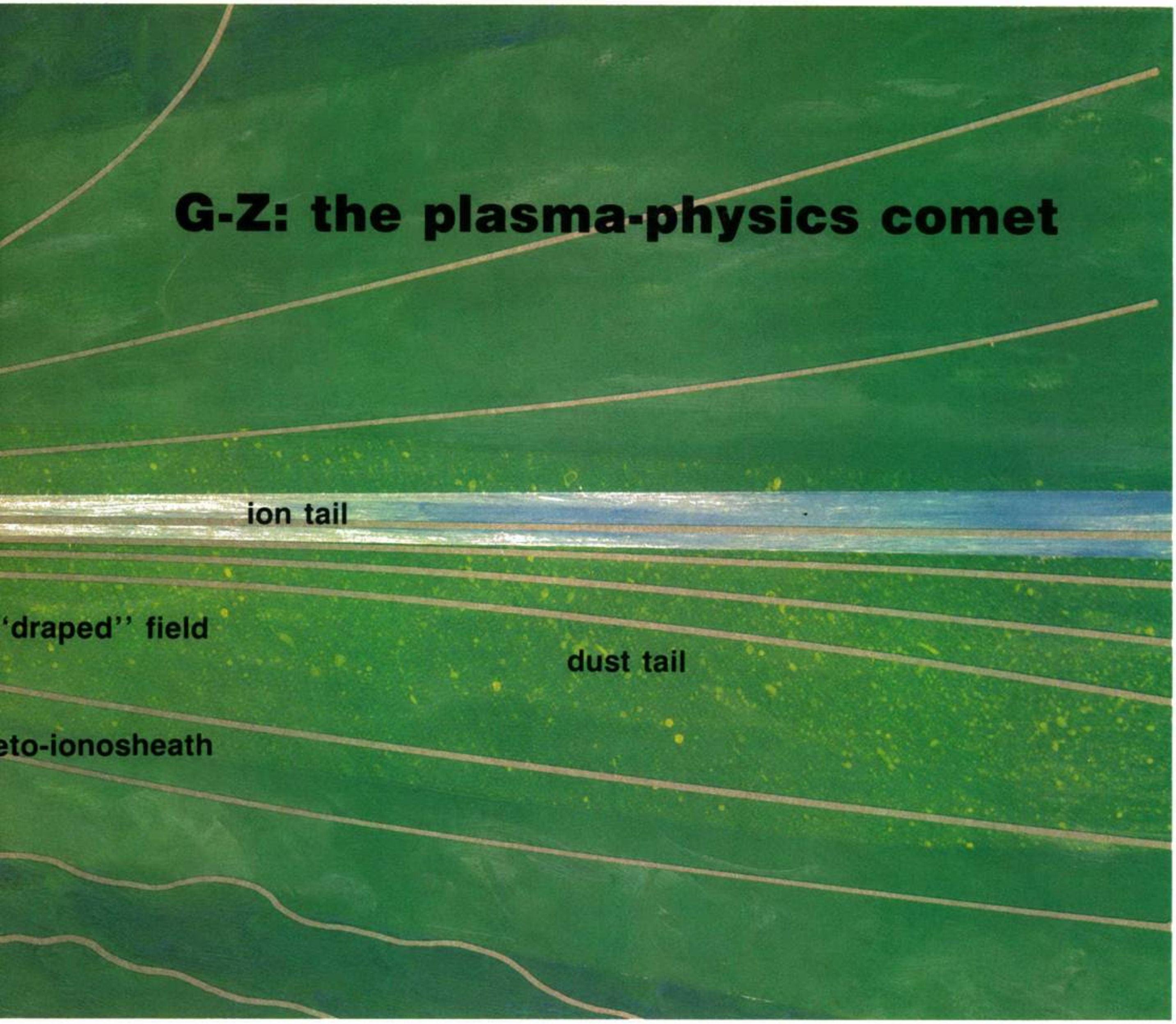
Soon after a comet "turns on" and begins to inject its molecules into space, it develops a diffuse halo of gas called the coma. Small at first, the coma soon grows to 100,000 kilometers in diameter. (Even though escaping molecules move rapidly, it still takes them several days to reach the edge of the coma.) Sunlight — particularly ultraviolet light — and the particles and fields of the solar wind impinge on the cometary coma, altering it profoundly.

When a molecule sublimes from the cometary nucleus, it is electrically neutral; that is, the positive charge of the atomic nuclei and the negative charge of the molecule's electron cloud balance each other. However, when a photon strikes the molecule, it may give up energy and knock off one of the molecule's electrons. The coma soon becomes a mix of ions and electrons — an ionized plasma.

But when the coma encounters the solar wind, trouble begins. The solar wind has an embedded magnetic field and is moving outward from the Sun at some 400 kilometers per second. Since plasma cannot readily move across a magnetic field, and since the solar wind's magnetic field is flowing rapidly outward from the Sun, cometary plasma gets dragged along with the solar wind to form the comet's tail. The tail may easily extend several million kilometers in length. Before the space age, comet tails were the best evidence astronomers had for the solar wind's existence.

From the solar wind's point of view, a comet is a huge obstacle in its path. Before ICE's mission, some scientists had predicted that the solar wind's onrushing particles and magnetic fields would pile up in front of the comet to form

G-Z: the plasma-physics comet



a "bow shock" — an effect that happens when the solar wind encounters Earth. Instead, ICE reported evidence that a process called mass-loading occurs. Not all the molecules leaving the comet become ionized. Some remain neutral and flow upstream in the solar wind. (Remember, the solar wind and the comet's coma are both nearly empty space.) Eventually, though, every molecule meets an ultraviolet photon and becomes ionized. As soon as it is ionized, the ion is immediately picked up and carried away by the solar wind's magnetic field. Since the solar wind must work to accelerate these ions, it slows down and compresses, becoming hot and turbulent upstream of the comet. This is the interaction zone detected by ICE.

As the solar wind's magnetic fields fold around the comet, they are assimilated into the cometary plasma. Some drape themselves over the comet like strands of cooked spaghetti, then slough off and flow downstream. Other magnetic field lines are dragged through the denser parts of the ionized coma and fold sharply back on themselves. These fields come together in the tail where they generate electrical currents. ICE seems to have detected hairpin-bend magnetic fields in the tail as well as the predicted electrical current.

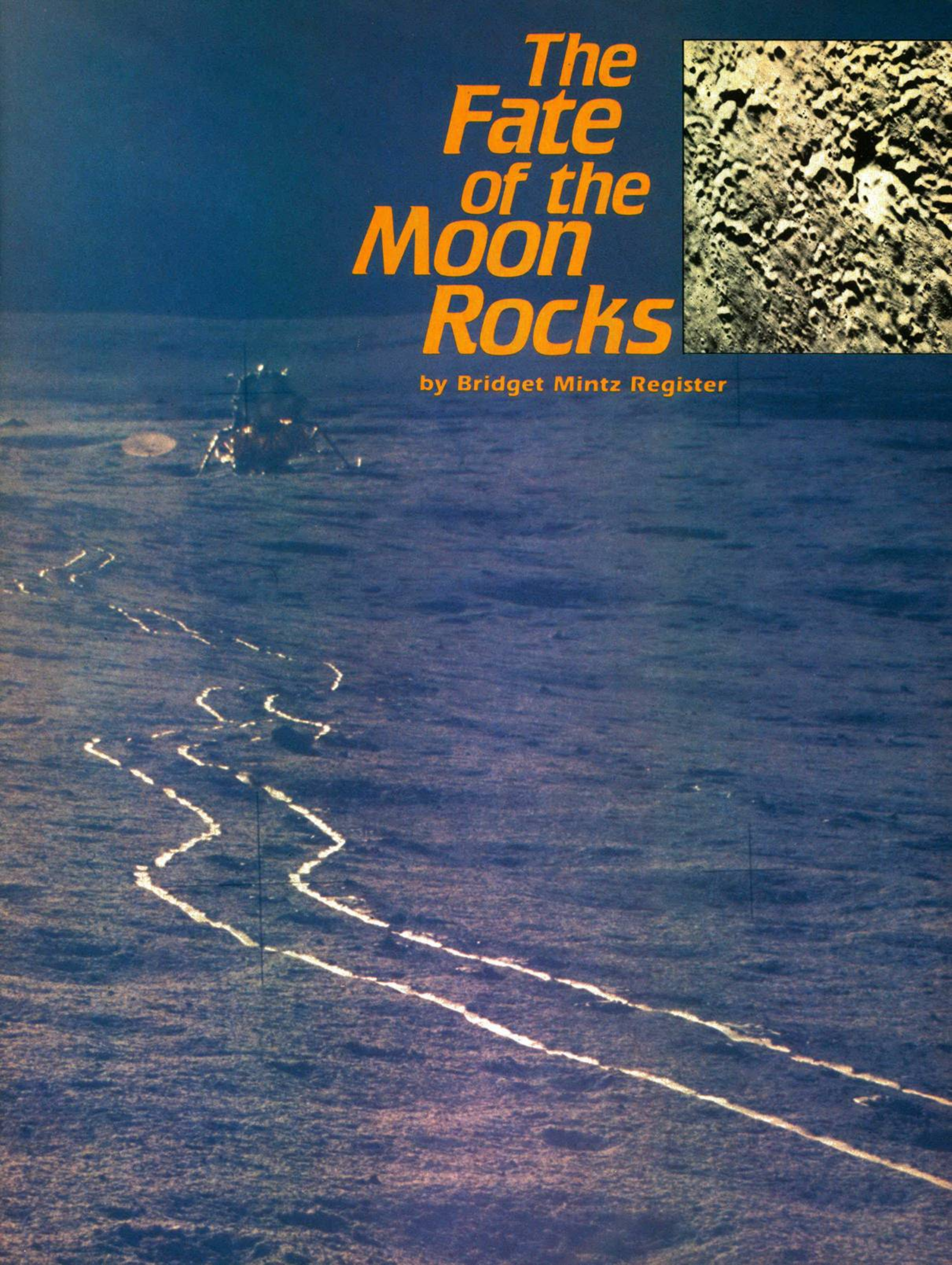
ICE revealed that comets are more complex and scientifically interesting than previously expected. Project Scientist Tycho von Rosenvinge noted: "It's apparent that we have a very rich base of data. But it's going to take us a lot longer [than two days] to understand it." With direct measurements of physical parameters to plug into the cometary models, astronomer's models of comets will be far more realistic. According to Brandt, "[Our current] models are going to have to confront reality."

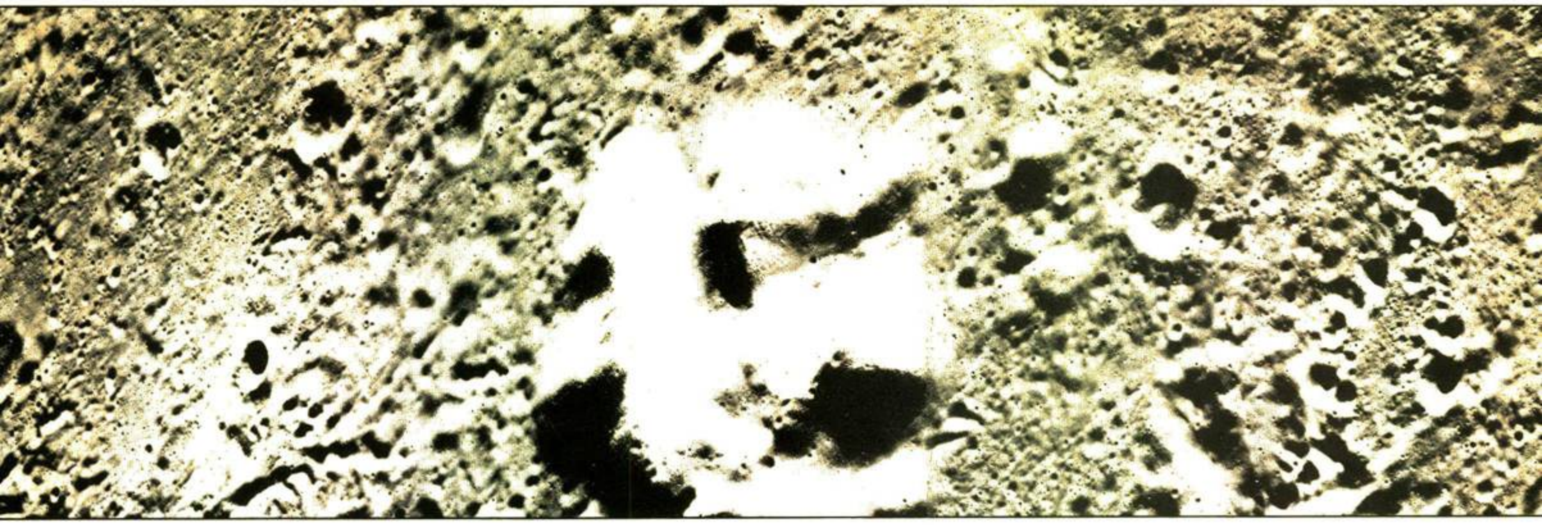
Possibly, even after all the data on fields, currents, molecules, and ions are evaluated, the ICE mission will seem pretty esoteric. Perhaps it was. But as Brandt pointed out, "The ICE instruments were focused and most efficient for investigating the processes of ionized gases, magnetic fields, and other plasma physics processes . . . Think of the comet environment [as a place] where there are ionized gases, magnetic fields, and electric currents flowing around unconfined by magnets and copper wire. There is *no way* we can report on ICE without mentioning plasma physics and trying to communicate it."

Apollo 14 photo courtesy NASA

The Fate of the Moon Rocks

by Bridget Mintz Register





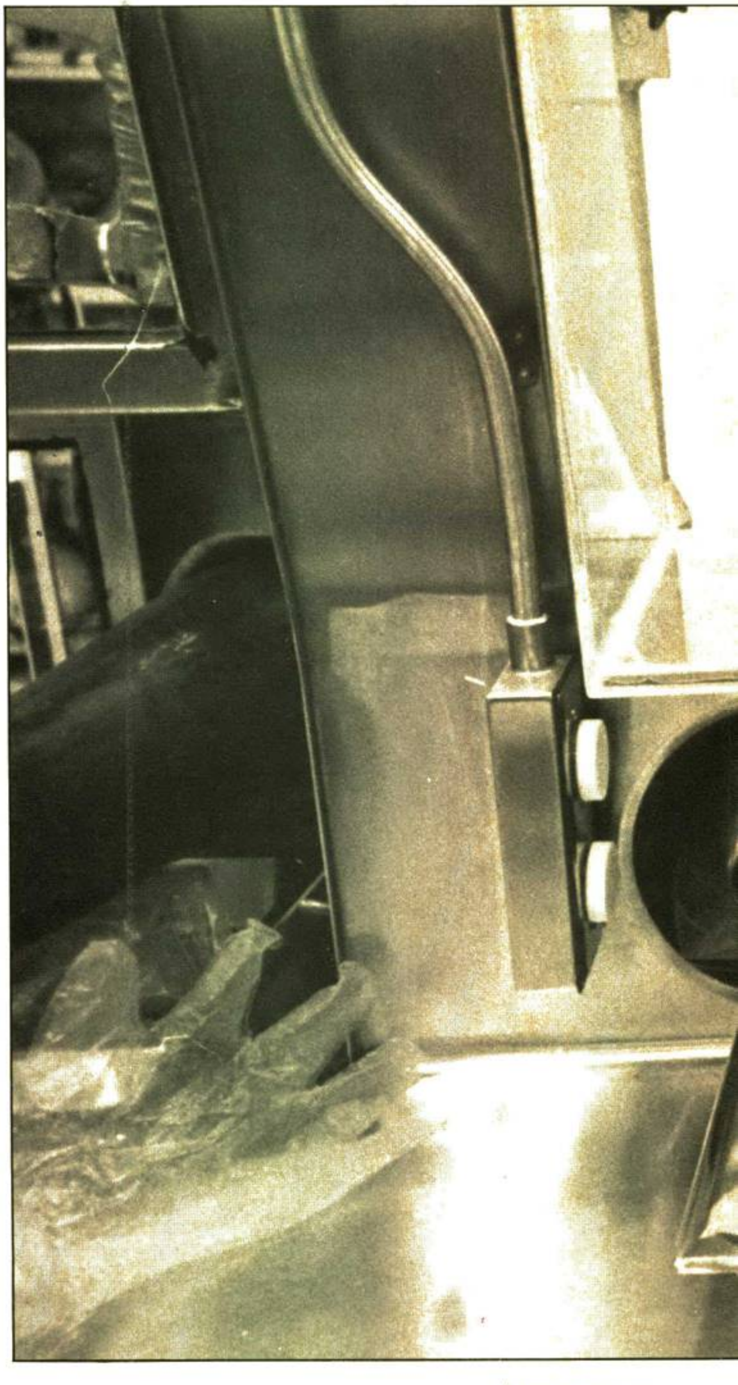
Say the words "Moon rock" and most people yawn. But not the researchers and staff of the Lunar Curatorial Facility at the Johnson Space Center in Houston. This small group of planetary scientists will tell you that not only haven't the Moon rocks revealed all their secrets, but also much of what was learned about the Moon from early studies of the rocks is — if not flat wrong — at least incomplete.

The Curatorial Facility is home to the bulk of lunar material returned by the six Apollo missions. It serves both as storage site and research center for continuing studies of the Moon rocks, not to mention Moon soil, Moon core samples, Moon sand, and Moon dust.

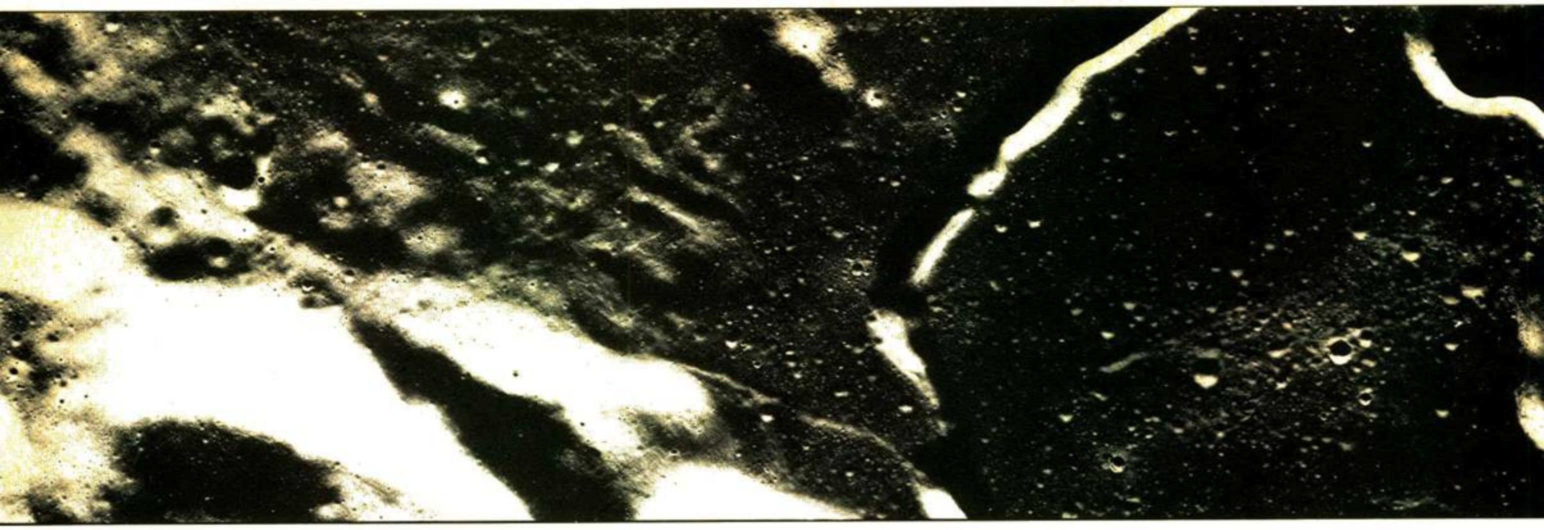
As a warehouse for literally out-of-this-world wares, the facility was designed with one imperative — to prevent contamination of the samples. Since nearly everything on Earth is a contaminant, that was no easy task. Take lead, for example. A single drop of solder contains more lead than there is in all 382 kilograms of lunar materials. Lead, even in the minute amounts found, is critical to determining the age of the samples. Other, more common contaminants also threaten the purity of lunar material: oxygen reacts with iron particles in the lunar materials to produce rust; water mixes with other constituents and produces clays; airborne dust contains a smorgasbord of contaminants. And should a researcher's gold ring graze a sample, in the words of the facility's Associate Curator John Dietrich, "Somebody might announce a gold strike on the Moon."

At first, Dietrich explains, the facility planned to house the lunar materials in their home environment — a vacuum. This turned out to be technically impossible. So, to maintain ordinary atmospheric pressure, the scientists settled on nitrogen, which is inert and non-reactive. This was the only earthly atmospheric component that wouldn't contaminate the samples.

The Apollo treasures, therefore, are stored and studied in cabinets filled with nitrogen gas. Rubber gloves coated with Teflon are fitted to the cabinets' glass walls, allowing researchers to handle the samples without ever touching them. To prevent contamination by the inevitable glove



Right: This rock, nicknamed "Big Bertha" for its unusual size, was picked up by Apollo 14 astronauts on their mission to Fra Mauro crater in February 1971. Across the top of the page is a panorama of lunar terrain taken by the mapping camera in the Service Module during the Apollo 15 mission. NASA photos.



leak, the cabinets' nitrogen gas pressure is slightly higher than external air pressure in the vaults or labs. In the event of a leak, nitrogen flows down the pressure gradient and out of the cabinets, keeping air from flowing in. In addition, the air in the labs and vaults is carefully filtered and kept at a slightly higher pressure than in the rest of the building. This double pressure-barrier keeps unfiltered Houston air from entering the sample areas.

One vault stores samples that have already been analyzed. Each such sample, regardless of its final condition, is returned to the vault. A detailed dossier, explaining precisely what analyses were performed, is maintained for each sample. A second vault is reserved for samples that have never been analyzed and remain in pristine condition. Before entering the storage vaults or labs, researchers must don "bunny suits" — standard clean room suits that cover all clothing and include covers for shoes and caps for hair.

Some lunar samples can be examined as they are, but when a sample must be cut open, it is carefully and slowly sawed, without lubricants, using a diamond-edged stainless steel blade. The saws are enclosed within nitrogen cabinets into which the samples are transferred. Each step of the sawing is carefully photographed to record the original location of every new sample. Just how slowly are the rocks opened? Chief Curator Doug Blanchard says: "A five-centimenter by four-centimeter rock is a *one-month* project."

According to Blanchard, 74% of the lunar samples returned by the Apollo astronauts remain untouched, 3% are out on loan, 5% have been studied and returned, 2% are being used for display and educational purposes, and 2% have been "used up completely" by destructive analytic techniques. The remaining 14% of the collection is stored at Brooks Air Force Base in San Antonio, Texas, against the chance of a catastrophe at the facility.

But what can these carefully preserved alien materials tell us that they haven't already? Blanchard replies: "We went to the Moon to find out about its origin — and we still don't have a clear picture." He adds that the lunar materials have taught us that the three main pre-Apollo theories of lunar origin were just too simple.

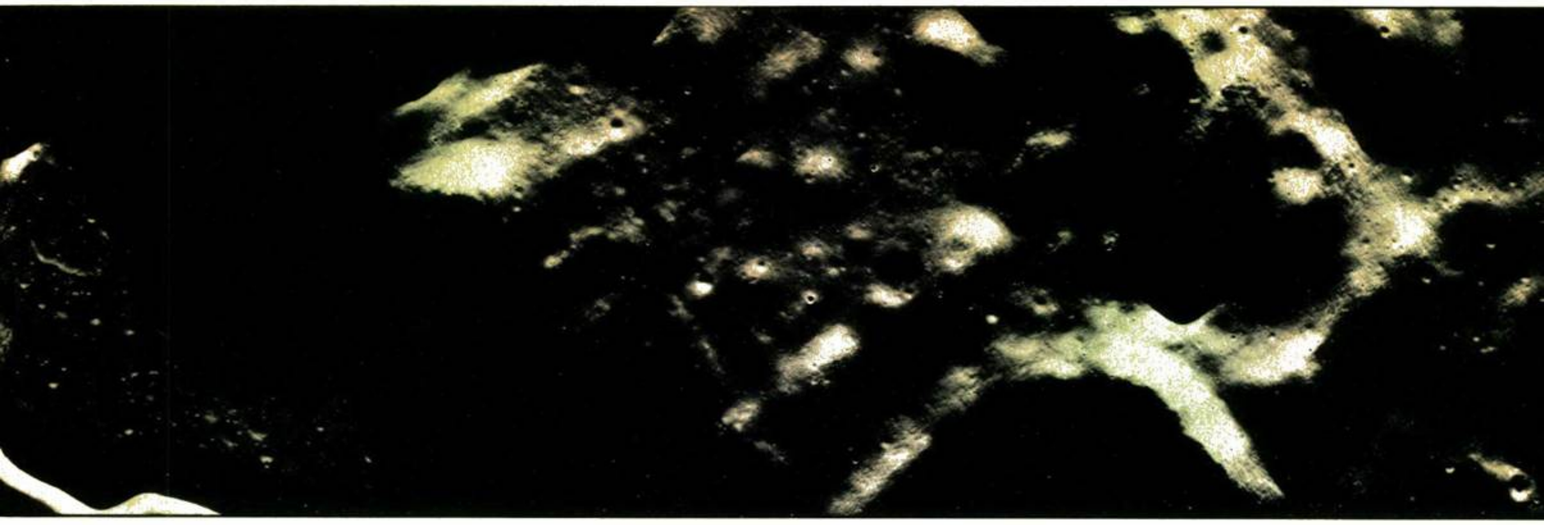
One of these theories proposed formation of the Moon by fission from Earth. A second advanced the idea of co-accretion, a simultaneous formation of the Earth and Moon from the same region of pre-planetary dust and gas. The third theory called upon the gravitational capture of a wandering Moon that had its origins elsewhere in the solar system. The capture hypothesis is unlikely, scientists feel, because it depends too heavily on special encounter circumstances. "Capture," Blanchard admits wryly, "has real physics problems." With the co-accretion and fission theories, the difficulties lie in what's been learned about the Moon's chemistry through techniques like X-ray fluorescence, mass spectrometry, and measures of different isotopic ratios.

Isotopic dating — measuring the ratio of one element to its decay product and comparing this with the known decay rate — gives the same age for the Earth, the Moon, and most meteorites: 4.6 billion years. And the crustal materials of the Earth and Moon (iron, aluminum, magnesium, calcium) are similar, though the relative proportions differ. But compared to Earth, the Moon is seriously depleted in volatiles — elements with low melting points such as zinc, bismuth, indium and cadmium. The Moon also has few metals such as nickel and gold.

According to Blanchard, these differences mean that the Earth and Moon simply could not have formed from the same pre-planetary cloud, nor could the Moon have fissioned from Earth. If either had occurred, the Moon wouldn't lack volatiles and metals to the degree it does. Yet the Moon's age and crustal similarities mean that it's not a totally alien body, either.

Current theories of lunar origin attempt to resolve these problems by a synthesis of capture and fission. They propose that at one point in Earth's early history, a large planetesimal collided with our planet. Such a collision would have forced Earth to spew out huge quantities of surface material. If this happened after the Earth had differentiated — when its heavy materials sank toward the core while the lighter rocks floated to the top — then, these theories suggest, our present "similar-but-different" Moon could have accreted from the debris. The Moon may also have gathered up additional Earth-orbiting planetesimals as the process accelerated. Several variations of this basic model were presented at a recent conference on the origin of the Moon.

Such theories result from continued analysis of the Apollo samples, as do new questions about the accepted model of lunar evolution. Graham Ryder, a senior geologist at the Curatorial Facility, explains: "Just by looking at the rocks, it was evident that something happened 4.6 to 4.4 billion years ago which involved



Allocating a Precious Resource

According to Graham Ryder, a member of the Lunar and Planetary Sample Team, all lunar samples are considered "national and international treasures," not just the investments of scientists. Consequently, samples are doled out sparingly to researchers around the world only after careful consideration of each proposed study.

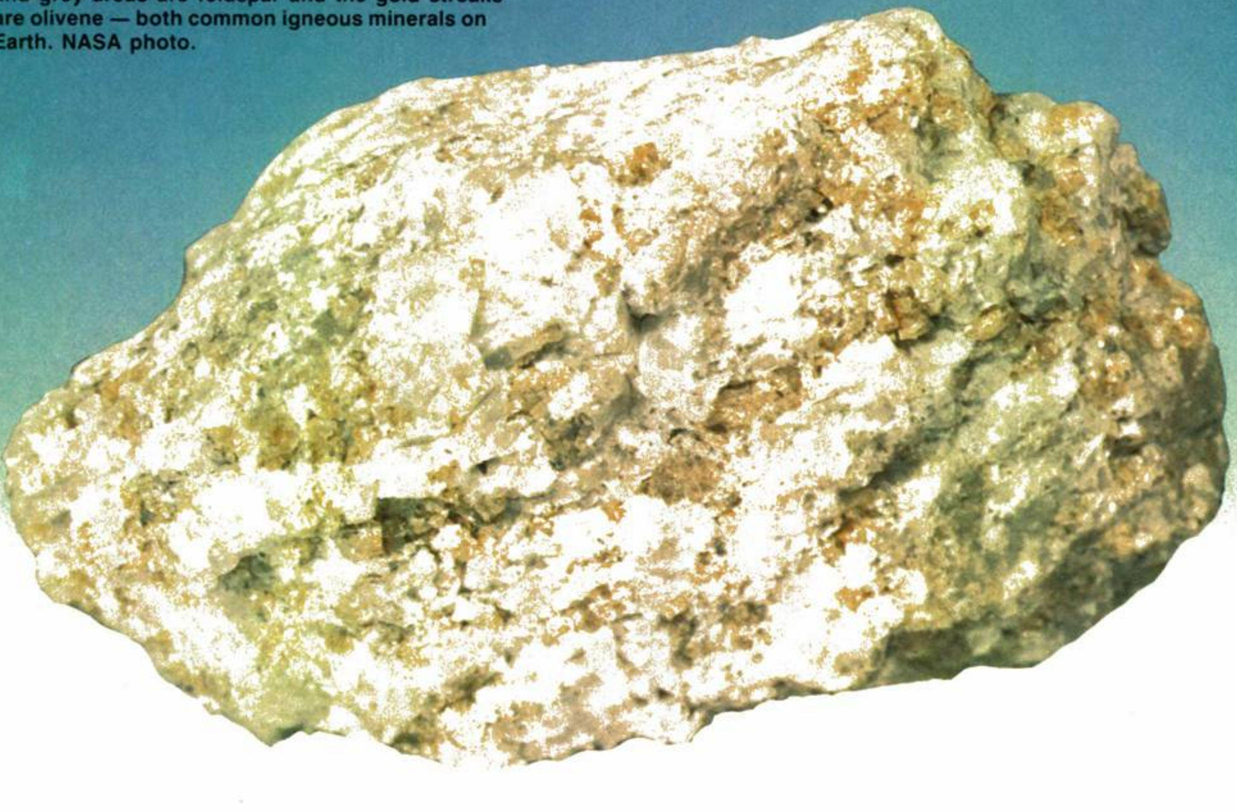
The Lunar and Planetary Sample Team, a group of researchers organized to advise NASA on the disposition of lunar samples, meets quarterly to review research proposals. Ryder explained that each request must state, in detail, how much and what type of sample is wanted and the sort of study to be conducted. Denials are rare and often take the form of asking the researcher to define the proposal better. Upon approval, an appropriate sample is delivered to the researcher within a few months. The entire process, from submission of a proposal to sample delivery, may take up to six months — barring funding problems, which are dealt with elsewhere.

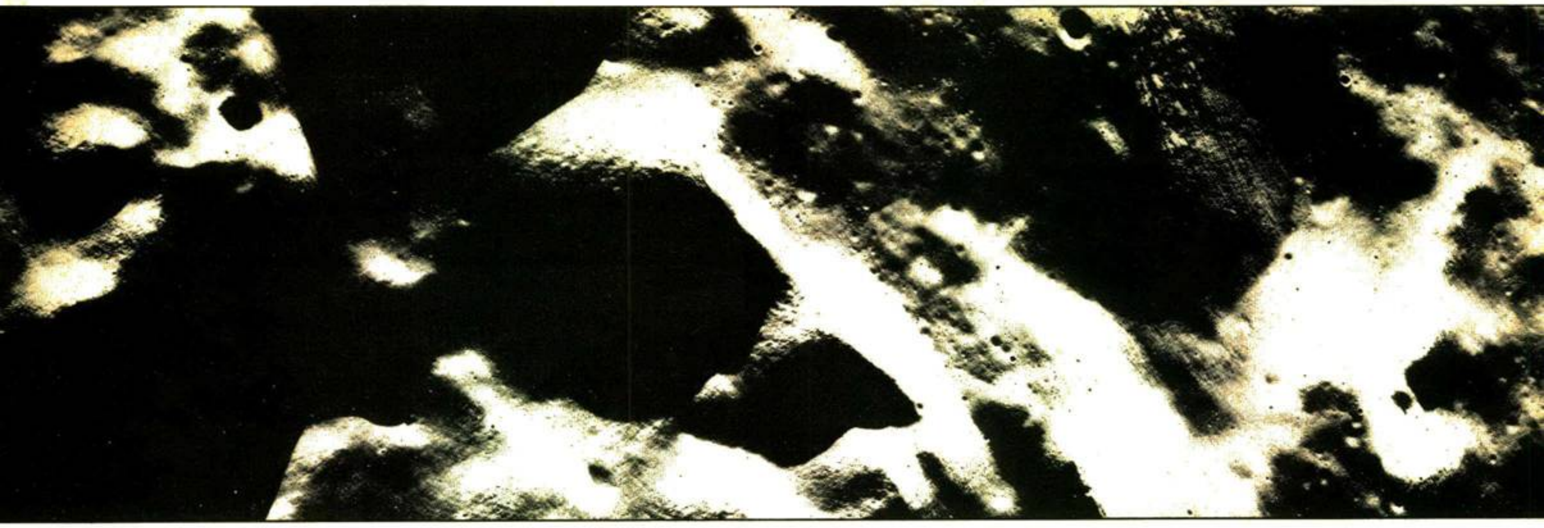
How much lunar material does the patient researcher finally receive? From one-hundredth of a gram to the maximum of a tenth of a gram.

Why such flyspeck-sized samples?

Doug Blanchard explains, "We don't give out bigger samples than necessary. And most people are very adept at using small samples."

This is a sample of the lunar highlands' crust; the white and grey areas are feldspar and the gold streaks are olivene — both common igneous minerals on Earth. NASA photo.





massive melting of at least half of the Moon and possibly all of it." As with the Earth, this event separated the Moon like a layer cake, with lightweight aluminum-rich materials rising to the top of a massive "magma ocean" while denser matter sank.

The next phase of lunar history, ending about 3.9 billion years ago, was marked by heavy meteoric bombardment. Ryder says this completely reworked the Moon's exterior and, incidentally, gave planetary geologists a baseline from which to estimate the age of any planetary surface by comparing the extent of its cratering to the Moon's.

About 3.3 to 3.6 billion years ago, the volcanism began which produced the smooth maria — the last event of note in lunar geologic history. And it is volcanic samples from the maria — basalts — that have led Ryder and others to question this model, especially the notion that one single event differentiated the Moon into layers. Several varieties of basalts have recently been examined and, Ryder asserts, "No simple model explains what we've found."

Other questions related to the problems of lunar evolution and origin remain. For example, there are the mascons, extra-dense regions associated with all the maria that are more than 200 kilometers in diameter. These exhibit excessively high concentrations of mass, which produces a local gravitational field about 1% greater than that of surrounding regions. While the mascons may result from layers of very dense lava filling the large basins — or might even be the remains of impacting bodies — nobody really knows what they are.

Other lunar curiosities include the Moon's offset center of mass and its crustal density. The Moon is "lopsided" — its center of mass lies about 2 km closer to Earth than its geometrical center. In addition, the crust on the Moon's earthside hemisphere is only 60 km thick whereas the farside crust is 100 km thick. Given the eons that have elapsed, the Moon should have long since turned its other side toward Earth. Because it hasn't, the earthside crust must therefore be denser than the farside's. Why?

Nobody knows.

Another question the Moon rocks may yet answer is the problem of lunar magnetism. The problem is — where is it? Measurements by lunar-orbiting spacecraft show no Moon-wide magentic field. Yet samples from all the Apollo missions display residual magnetism, termed

Cooking Up a Lunar Recipe

Can lunar soil support large structures — or grow corn? Can you make concrete from it?

Questions like these which concern uses for the Moon, arise from recent interest in space commercialization and can be answered only with large samples of lunar materials — hundreds or thousands of grams per experiment.

While the planetary scientist community generally favors such inquiries, handing out kilogram-sized samples is simply unimaginable. To avoid this, a small study is underway at the Curatorial Facility to investigate computer simulation of crucial properties of lunar soils.

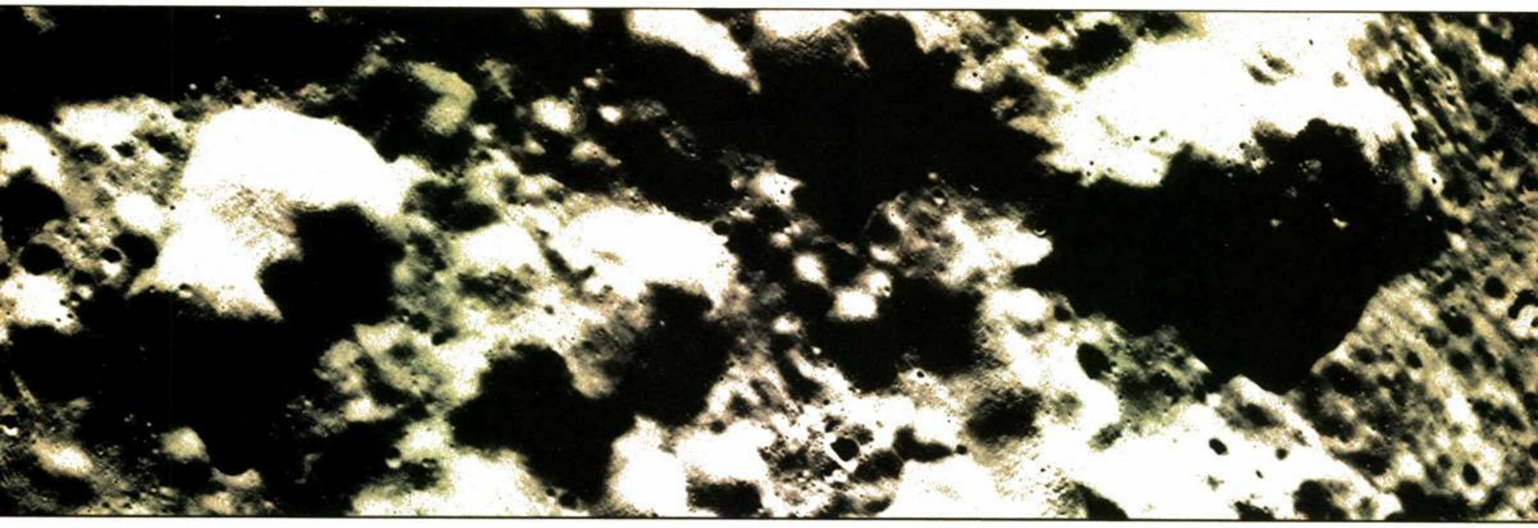
Northrop Services geochemist Judith Allton, charged with this task, explains that lunar soil differs from terrestrial soils in both particle size and mineral content. But more importantly, the bare, unprotected face of the Moon has been subjected for eons to the ravages of micrometeorites, solar wind, and radiation.

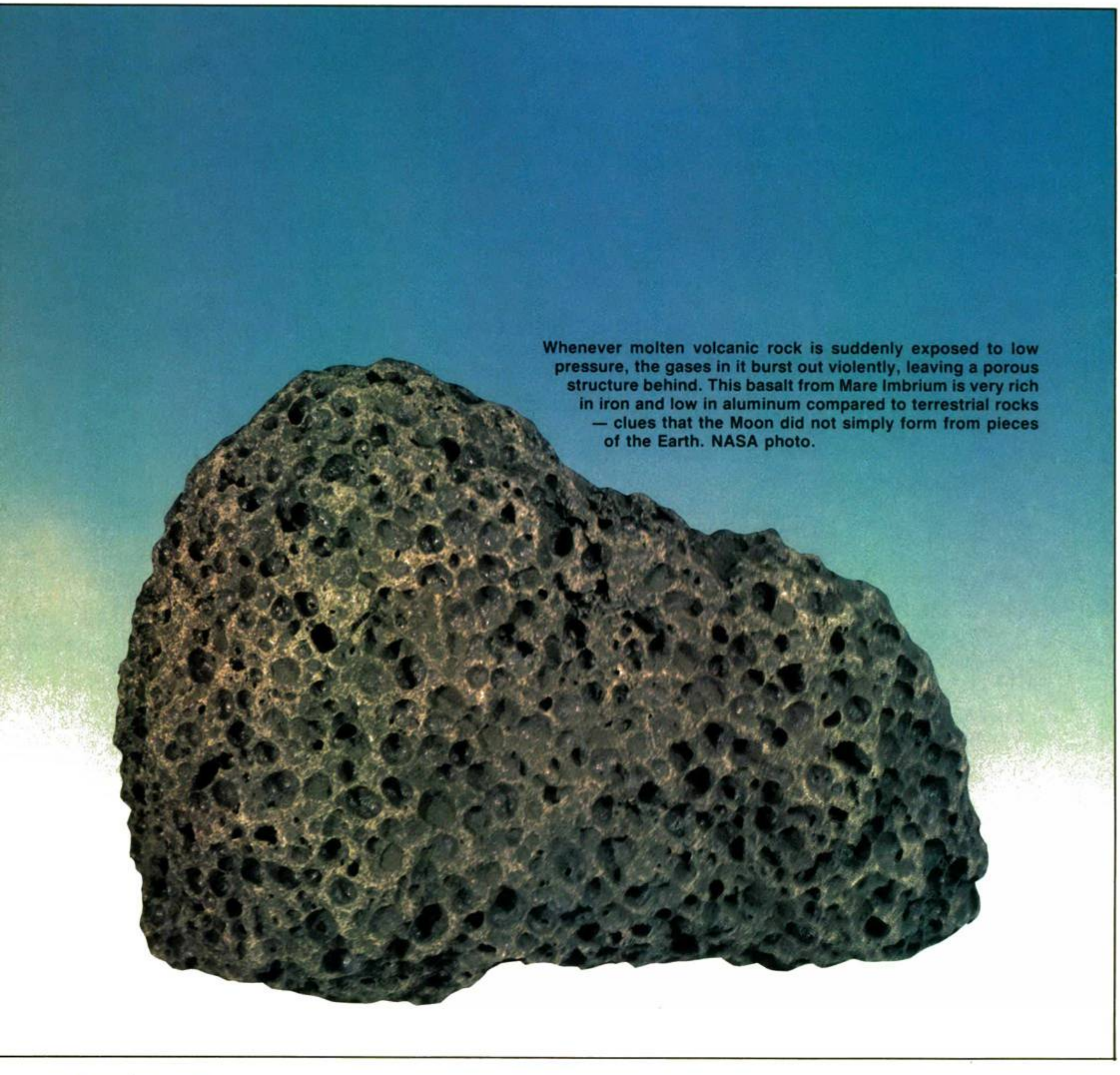
The solar wind has injected into the soil, atom by atom, the elements hydrogen, helium, carbon, and nitrogen. Micrometeorite impacts have not only shocked and structurally altered the soil grains into something very unlike Earth soils, but they have also fused them into tiny, glassy clumps rich in free iron. These accumulations of iron have electrostatic and magnetic properties that may be of great engineering importance.

Allton is trying to discover combinations of terrestrial materials that can simulate, at least partially, some lunar soil properties. So far, she has found that mineral composition, general chemical make-up, and distribution of soil particle sizes can be simulated with some success. What's hard to duplicate are the effects of solar wind, micrometeorites, and radiation.

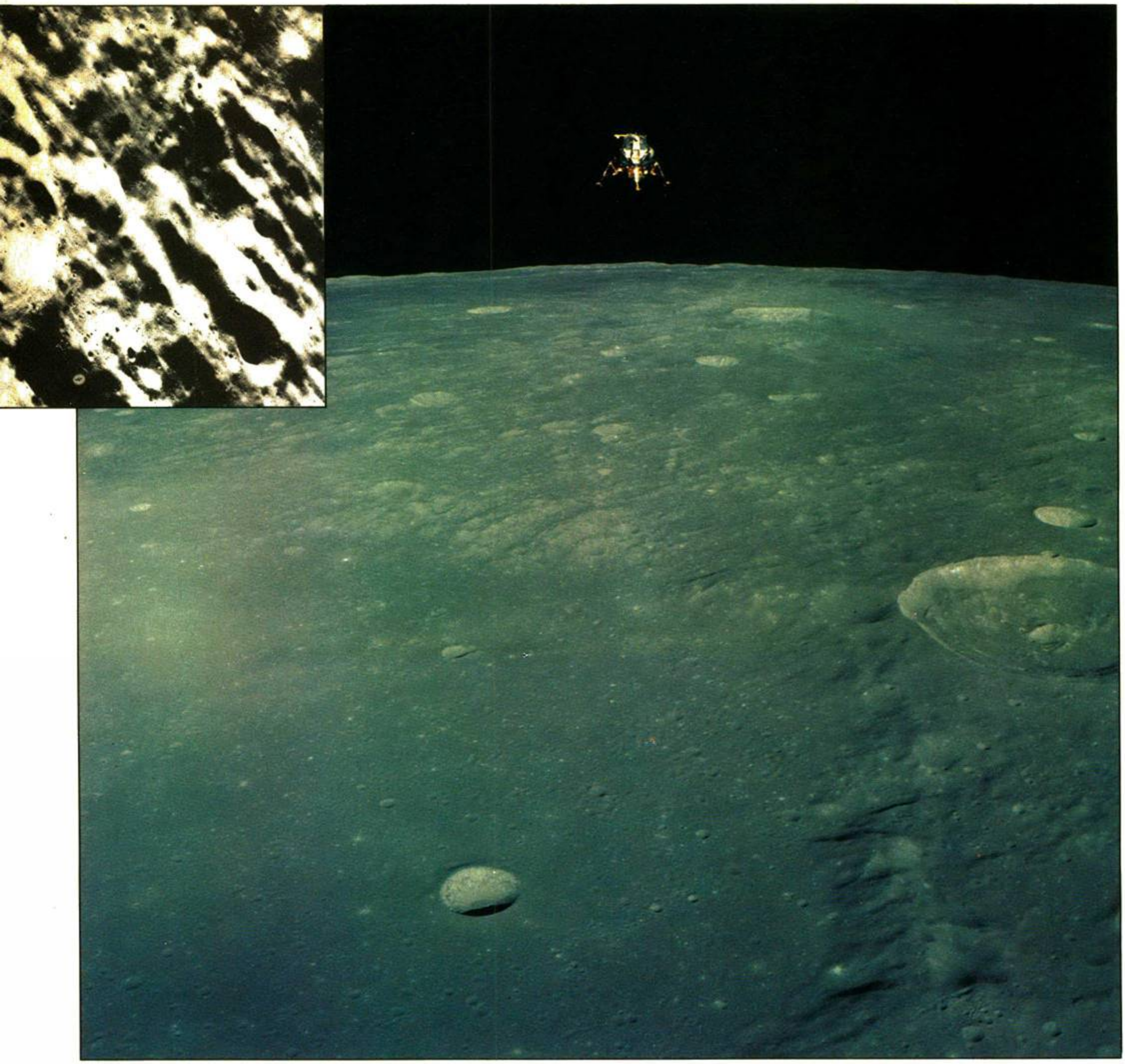
The study is only beginning, but Allton has established a tentative lunar "recipe." First, a researcher decides what chemical composition and soil particle size distribution he or she is after based on known lunar soil properties. Next, the researcher selects from a small group of terrestrial minerals those that closely approximate the desired chemistry. Each rock type must then be ground and sieved separately to achieve the right grain sizes. Finally, the resulting powders are mixed proportionally by grain size and rock type. The result is a reasonable simulation of a particular lunar soil.

Indeed, only one ingredient seems to be missing from Allton's recipe — a pinch of green cheese!





Whenever molten volcanic rock is suddenly exposed to low pressure, the gases in it burst out violently, leaving a porous structure behind. This basalt from Mare Imbrium is very rich in iron and low in aluminum compared to terrestrial rocks — clues that the Moon did not simply form from pieces of the Earth. NASA photo.



As Apollo 12's lander started its journey down to the lunar surface, astronaut Richard Gordon photographed it over Ptolemaeus crater (left foreground). Studies of lunar samples have raised many questions in the minds of scientists — too many to be answered with the data on hand. NASA photo.

natural remanent magnetism. This magnetism is a relic of the time, ages ago, when these rocks crystallized in the presence of a lunar magnetic field that has since vanished. What happened to it? Why did it disappear?

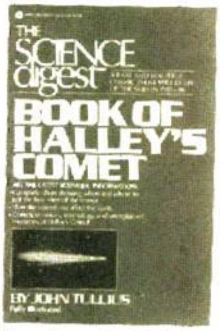
Nobody knows.

David McKay, another facility researcher, is studying the varieties of lunar soil, or regolith, to understand the early history of the Sun. He is searching for microscopic tracks etched on the rocks by energetic particles from the solar wind. Ancient lunar rocks, once exposed at the surface but since buried for millions or even billions of years, would preserve the tracks etched into them when they were exposed. These "fossil particle tracks" may tell us much about solar activity long ago. McKay has also suggested that we may even be able to find evidence in the regolith of the "terminal Cretaceous event" that annihilated the dinosaurs 65 million years ago on Earth.

But there is one overriding reason for continuing, indeed accelerating, the study of the lunar samples. McKay puts it succinctly: "The time has come to get back to the idea, abandoned after Apollo, of returning to the Moon permanently." Study of the samples in hand can not only tell us where the scientifically interesting sites are, but also, casting an eye toward using the Moon's resources, how such a lunar base could become a true step to the colonization of space.

Bridget Mintz Register is the Houston correspondent for Space World *magazine. She is also a freelance contributor to several other magazines specializing in space development and commercialization.*

Catch the Comet!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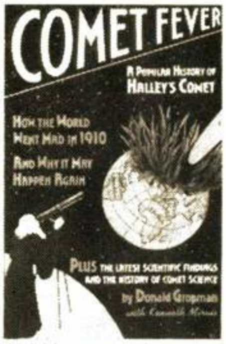
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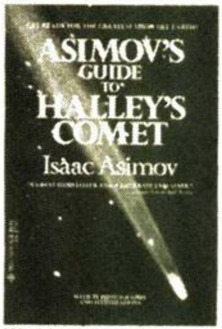
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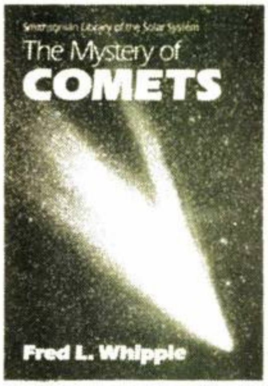
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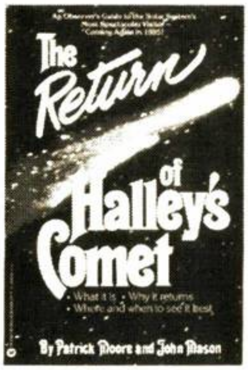
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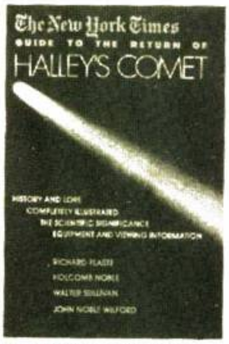
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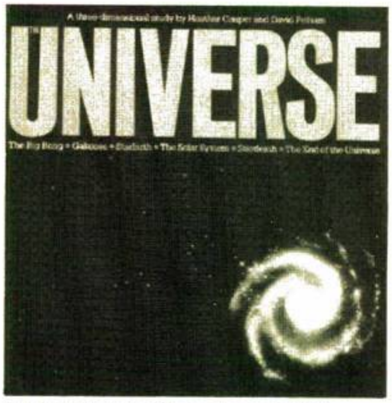

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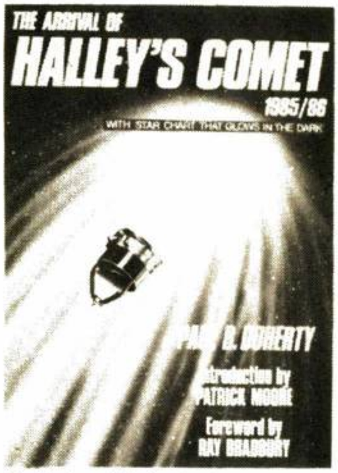
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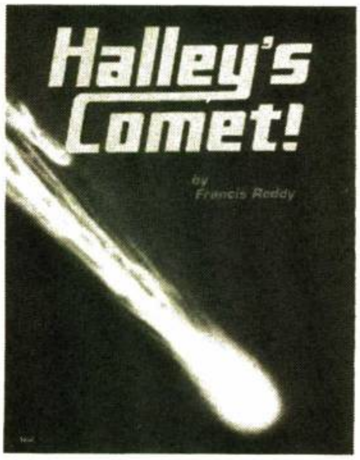
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ASTRONOMY
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Exploring the Tropic of Canopus

No star titillates northern observers more than circumpolar Canopus, the second brightest star in the sky. At magnitude −0.72, Canopus is in a class of its own — outshining by half a magnitude all other stars except Sirius. Although invisible at latitude 40° north, Canopus lurks a mere 2½° beneath the southern horizon and tempts northern observers because it is *almost* visible. Seeing Canopus is a challenge which requires some effort.

For observers in the southern United States, the late winter months afford an excellent opportunity for viewing Canopus. Located in Carina, the keel of the constellation ship Argo, Canopus appears as a splendid, low-lying adornment to the winter sky. It is situated south of Sirius and culminates 20 minutes earlier.

The prospect of glimpsing Canopus excited me even as a child, when I first discovered it on a star chart. The star's existence came as a surprise since it is seldom mentioned in books. Not knowing its exact declination, I prevailed upon my father to drive me to the southern Ohio countryside in quest of a perfect southern horizon. Unfortunately, the mission failed because Canopus still lay too far south.

The proximity of Canopus to the horizon was recognized by the ancient Greeks, who used it as an indication of latitude. In the 1st century B.C., the astronomer Posidonius of Samos judged Canopus to be just barely visible on the Isle of Rhodes; from nearby Alexandria, it rose 7.5° above the horizon. Using this, he estimated the circumference of the Earth to be 30,000 miles. However, ancient observations were inexact and the position of Canopus was a subject of dispute. The astronomer Eudoxos placed Canopus at the edge of a circle of stars invisible from Athens, while his successor, Hipparchos, thought it was actually visible there.

For many years, Canopus was believed to be some 300 to 600 light-years away, making it by far the most luminous of the bright stars — at least 80,000 times as bright as the Sun! Recent estimates have downgraded Canopus to the more reasonable figure of 100 light-years distant and less than 10,000 times as bright as the Sun. However, the old figures still appear in some modern tables of data.

The origin of Canopus' name is obscure. A Greek town with the same name existed in Egypt, but we can only speculate about any connection between the two. Perhaps the ancients thought the town was a favorable place for viewing the star.

Modern viewers may find Canopus at declination −52° 41.2′. From simple geometry, Canopus might be expected to graze a perfect horizon at the complementary latitude of 37° 18.8′ north. In observing this star, its visibility can be improved by two effects. First, atmospheric refraction bends light around the horizon by some 35 arc-minutes, making it possible to see that much farther beneath the theoretical horizon. In addition, viewing from a given horizon can be helped by elevation, depending on the observer's altitude. This effect amounts to one degree at 3,200 feet and increases with the square root of elevation. Nevertheless, in defining the threshold of visibility, it is best to ignore these effects at first and begin your search for Canopus at 37° 18.8′ north — a latitude which may aptly be dubbed the "Tropic of Canopus."

The Tropic of Canopus crosses the eastern United States north of Cape Charles, Virginia, then continues south of Richmond and through the city of Roanoke. It passes by Mammoth Cave National Park, Kentucky, Springfield, Missouri, and Wichita, Kansas, continuing on through Zion National Park in Utah. Finally, it arrives near the southern tip of San Francisco Bay, where it traverses San Jose.

I resumed my search for Canopus from Lick Observatory, Mt. Hamilton, California, hoping to find both good seeing conditions and a southern horizon. It was late February. Shortly after twilight turned to night, Canopus gleamed forth in its appointed place with unmistakable brilliance, shining orange like Betelgeuse and only slightly dimmed by atmospheric absorption. As I watched, its brightness first approached then exceeded Procyon and Rigel. It later occurred to me that the star's prominence was partially attributable to the altitude of Mt. Hamilton, which at 4,200 feet effectively lowers the horizon by 1° 9′ and adds 35′ of refraction. Canopus remained conspicuous and easily visible during the drive down the mountainside. The question immediately arose as to how much further north Canopus might be visible, and how easily it might be found at sea level.

On subsequent nights, I traced Canopus along the Pacific Coast Highway, beginning south of Santa Cruz. To my surprise, Canopus was visible at sea level — not only as far as the Tropic, but also north of it. My northernmost observation was just above latitude 37° 31′, north of Half Moon Bay at Seal Cove, over 13′ north of the Tropic where the effects of refraction brought it into view. Favorable conditions were necessary to spot Canopus at that latitude, as viewing over the ocean was complicated by persistent mist and the lights of fishing vessels. Ground haze and fog also took a considerable toll on the star, which glimmered deep red. Under these circumstances, Canopus was visible for some 15 to 30

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minutes, much shorter than the period of visibility predicted by spherical geometry which equates to 75 minutes for an object 20° above the horizon.

Unfortunately, I was unable to pursue Canopus farther north, since the Pacific coast loses its southern view. However, the most remarkable apparition of Canopus I witnessed was farther south at a point on the headlands above the Pacific, just a few minutes south of the Tropic of Canopus. The ocean air was transparently dark and clear, yet impregnated with a mist that cast halos around bright stars and planets. As I waited for Canopus to appear, I noted a dull glow on the horizon similar to the lights of a far-off city; since there was no city, I ascribed it to a distant fishing vessel. As the minutes passed, the glow brightened perceptibly at the tip of Argo's keel. Then suddenly, from underneath, Canopus burst forth like a searchlight in a searing yellow-orange blaze that became the second brightest star in the sky. Around it, the glow I had first noticed remained as a halo. Is it possible that under ideal conditions, Canopus can be detected through the trace of its halo in places where it does not itself rise above the horizon?

Readers interested in pursuing the quest for Canopus should be aware that now is the best time to do so for millennia to come. This star has just passed the northernmost position it can attain under the precession of equinoxes, and is slowly being carried southward and out of sight at a present rate of about 0.035′ per year. It is now at virtually the same declination as when the ancient Greeks observed it, having passed its northernmost position around 925 A.D. at a declination only 18 minutes north of its present position. A quintessentially southern star, Canopus is destined to pass within 10° of the South Pole around 14,000 A.D. On that same date, the brilliant star Vega will be within 5° of the North Pole!

The farthest north I've viewed Canopus was 13 minutes north of the Tropic at sea level; readers are invited to pursue the search further. Those who wish to do so should, of course, remember the effects of altitude. It seems certain that Canopus is visible much farther north from mountains suitably situated around San Francisco, Roanoke, and elsewhere. Airplane pilots might even be able to spot it at latitude 40° from an altitude of 20,000 feet or so. Observers farther south may also be interested in investigating the tropics of Achernar, Alpha Centauri, and Acrux. Some readers might even be surprised to discover they have overlooked the possibility of glimpsing Canopus in their own backyards!

Dale H. Gieringer
Oakland, CA

Peter van de Kamp and His "Lovely Barnard's Star"

It's a sunny but chilly winter's day as I walk along the Amstel River in Amsterdam. Close to the famous Thin Bridge, one of the most photographed places in town, I find the number I was looking for. The occupant's name is chiseled into the doorpost: "VAN DE KAMP." Here lives the man who has spent nearly his entire career searching for planets accompanying Barnard's star.

I ring the bell and van de Kamp pops his head out of the third-floor window to welcome me. A few minutes later, I am drinking coffee made by a young female student who addresses the aged astronomer as "professor." On the chimney are photographs of an IAU meeting from the distant past. A big, heavy desk is barely visible under papers and photocopies, most of them concerning the recent discovery of a companion to the dim star Van Biesbroeck 8 in the constellation Ophiuchus. A rather impressionistic painting hangs on the wall showing four people playing music together. The two violin-players are Peter van de Kamp and . . . Albert Einstein!

"I once played the violin with Einstein," van de Kamp explains. "Later, my friend and ground-floor neighbor, Joop Sjollema, made this painting of it."

Once again, I tell him that the reason for my visit is to discuss the discovery by Arizona researchers of a "planet-like star" in orbit around VB8. Is anyone better suited to comment on this than the Nestor of the planet-hunters?

"The reports in the press are quite muddled," says van de Kamp. "That companion was already discovered by Robert Harrington, a former student of mine. Everywhere teems with former students of mine. Robert had discovered an astrometric disturbance by Van Biesbroeck 8, which indicated the existence of a light-weight companion."

I ask if it is true that the Arizona team, including Donald McCarthy, wants to steal his thunder. Is there a marked difference between astrometric detecting and observing by means of infrared speckle-interferometry?

"No," says van de Kamp, "there never was any real competition between the astrometrists and the Arizona team. I know McCarthy very well, and there's no doubt of that. But what do you mean by the words 'observe' and 'see'? An observation, carried out in a wavelength region in which our eyes are not sensitive, using a special instrument which produces a picture after intensive computer processing . . . is that to be called 'see'? If so, the astrometrists also 'saw' the companion!"

It appears that van de Kamp is quite disappointed that the general public seems to value the recent observation more than the extensive astrometric work that was carried out earlier. Besides, the companion of VB8 is not a "real" planet, but rather a so-called brown dwarf — a kind of failed star. Automatically, our talk shifts to van de Kamp's own work. He has meticulously studied the proper motion of Barnard's star for more than 40 years and found that the star doesn't move in a straight line, but rather travels along a wobbling track. These minute wobbles seem to indicate that Barnard's star is accompanied by two Jupiter-sized planets. How did van de Kamp come to throw himself into this subject?

"In those days, I went to study at Utrecht for the simple reason that I could live there with my aunt and uncle. That kind of consideration was important then! At the Sonneborgh Observatory in Utrecht I studied under Nijland and van de Bilt. Van de Bilt had an enormous influence on everybody. He saw little future in the purely visual research being carried out by Nijland, who was an observer of variable stars, comets, etc. No, I had to throw myself into photography; that promised an exciting future! When Jan Oort moved to the United States some time later, Professor van Rhijn in Groningen, the successor of Jacobus Kapteyn, suddenly found himself without an assistant. Van de Bilt persuaded me to go to Groningen, although I didn't have my Ph.D."

In 1925, van de Kamp completed his doctorate at the University of California, and one year later in Groningen, he presented a paper entitled "Solar Movement With Respect to Apparent Faint Stars." Van de Kamp hands me a beautiful old book with parchment-like pages crammed with formulas, tables, and reflections on the movement of the Sun. Although the book is strictly about the Sun and not about the proper motions of other stars, it seems that in this book the future astronomical career of Peter van de Kamp was being laid down.

"Let me see, how did I find my way to that lovely Barnard's star," muses van de Kamp. "The large proper motion of that star was discovered in 1916 by E.E. Barnard, and it was reasonable to think that any

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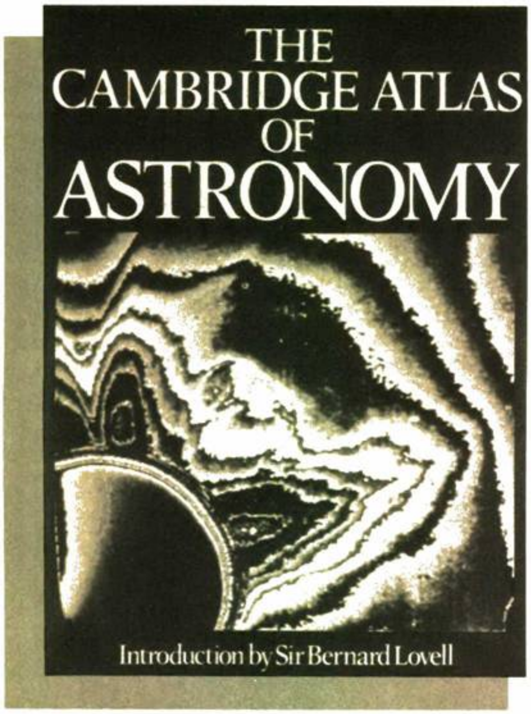
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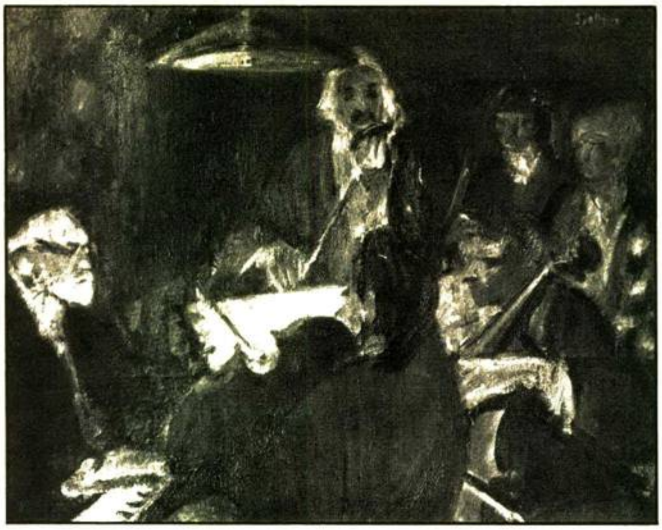
Van de Kamp, in the foreground, once played violin with Albert Einstein, at top. This portrait of the event, painted by Joop Sjollema, hangs in van de Kamp's Amsterdam apartment.



disturbances would be most easily detectable by close, fast-moving stars. The companions of Sirius and Procyon were discovered astrometrically by the disturbances they made in the movements of the primaries. This was, of course, before astrometry could be carried out photographically. I thought that with the help of photography everything should go much easier!"

Van de Kamp found dozens of stars which showed a clear disturbance in their proper motions. In most cases, the measurements clearly indicated the mass and distance of the companion. In all cases but one, however, the companion was a star too dim to be visible from Earth. But the companions to Barnard's star seemed to be planets. In 1937, van de Kamp started his observations on this fast-moving object and in 1956 he published his results. By that time, he had been observing the star for nearly 20 years.

"In some years, we exposed as many as 6,000 plates," remembers van de Kamp. "Every clear night we spent at the telescope, for if you want to know anything specific about a companion, it is necessary to carry out a long series of observations.

"The observations of VB8 are, of course important, because we now know something about the brightness and temperature of the companion. But a single observation cannot conclusively establish the distance to the primary and the orbit of the companion.

"In observing Barnard's star, we arranged everything as well as we could to eliminate systematic errors. For instance, we photographed the star when it was near the meridian. Most plates were exposed for 30 seconds, and all the photographs were measured on a manual measuring machine.

"Those first results had to be adjusted a little in successive years, but it is evident that Barnard's star is being attended by two planets, with 0.7 and 0.5 times the mass of Jupiter. That is to say, I *think* that I have discovered them. Of course, it is possible that more planets orbit Barnard's star, but they are not massive enough to show their existence in the proper motion of the star. And perhaps other stars also have planets ready to be discovered in this way, but who is there to observe them?"

Van de Kamp sounds rather embittered when he says: "Proxima Centauri could be a very good candidate. But in the southern hemisphere, nobody takes care of this star!"

In the afternoon, Joop Sjollema pays a visit to van de Kamp. He is an elderly painter who walks cautiously, lest he disturb us, and who talks in French for half of his sentences. Sjollema owns the house and lives one story below van de Kamp. The two men visit each other regularly. Sjollema likes listening to our talk and shuffles downstairs to get his sketching paper and pencils. "An interview is a marvelous subject for a drawing!"

Carefully, I touch upon a delicate subject: In recent years, there has been much discussion about the validity of van de Kamp's observations. It is said that his measurements were not accurate enough and failures occurred because the Sproul Observatory refractor, with which the work was done, was imperfectly mounted. In short, van de Kamp is thought by some to be the victim of bad measurements and technical shortcomings, and perhaps the planets of Barnard's star don't exist at all.

"Look," he says resignedly, "there are many people who don't work themselves but still look for mistakes made by others. I just let them talk; all I can do is tell them how you have to handle such a problem: by means of a long series of observations. Is there any doubt about your results? Then just go on with your measurements for another five years. And still another five. I have studied Barnard's star for over 40 years, and in the last 10 years the interpretation has not changed. The original photographic plates have all been measured again on automatic measuring machines and the results are the same. And the astrometric stability of the telescope I used has been proven. For every star with a disturbed proper motion, there are at least 10 stars without such a disturbance. Those stars follow a straight path between the background stars. The disturbances in the path of Barnard's star are much greater than the measurement errors that show up in the 'undisturbed' stars."

I ask van de Kamp what we have to do next — wait for the first direct observations of the planets of Barnard's star? Van de Kamp thinks that could take quite a long time. "I estimate their visual brightnesses at magnitude 30, and that is the limit even for the Hubble Space Telescope. But don't forget: these are real planets, in contrast to the brown dwarf companion of VB8. Even in the infrared, Barnard's star shows no peculiarities. I tend to think: so far, so good!"

The student is leaving to go home: "Goodbye, professor, see you tomorrow!" While van de Kamp looks for some pictures in the other room, Joop Sjollema stands at the window, enjoying the view of the most beautiful place in Amsterdam: the wide Amstel River, the Thin Bridge, and the stately houses on both sides of the canals.

"And over there you can see my future," Sjollema mutters, pointing to the old men's home across the Amstel. Van de Kamp cannot find the pictures, but promises to send them to me.

After dedicating his complete astronomical career to Barnard's star, van de Kamp is no longer active in the field. Following a very serious illness, he has to stay quiet. "The doctors have forbidden me to give lectures anymore. But I try to keep up with all the developments. I correspond with Robert Harrington in the United States, and I am writing a new book, as a successor to *Stellar Paths*. The title is *Planetary and Dwarf Companions of Stars*. And of course some chapters now need to be dedicated to those gas globes they discovered in Arizona."

Whatever Hipparcos (a proposed astrometric satellite observatory) or the Space Telescope discover in the future, the 84-year-old astronomer Peter van de Kamp has put his stamp upon the study of this star and its possible companions. But I think its name needs to be changed as soon as possible. At least I will call it van de Kamp's star from now on.

Govert Schilling
Utrecht, The Netherlands

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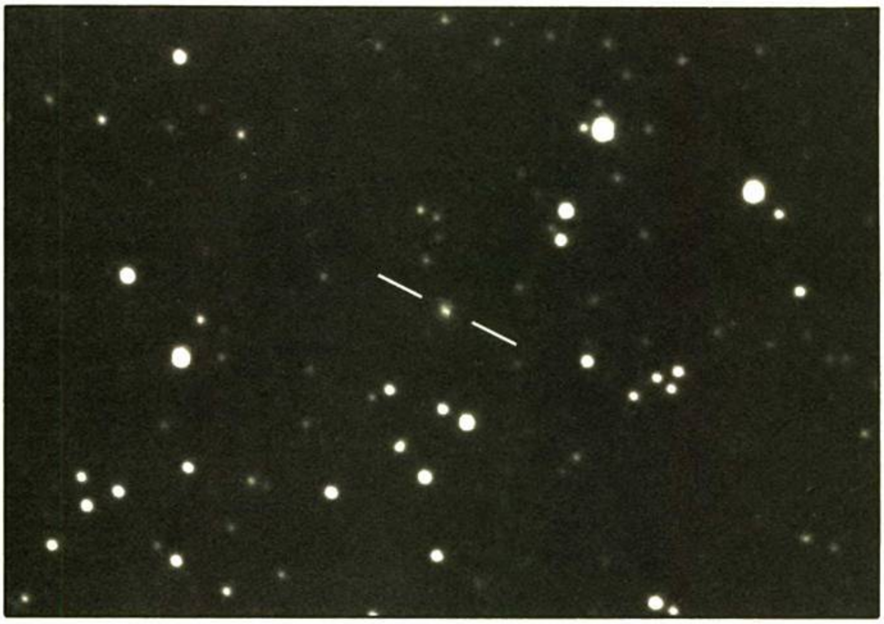
Halley: Last Look Before Perihelion



Right: On September 14th, comets Halley (between tick marks) and Giacobini-Zinner (right center) lay within 2° of each other in the constellation Taurus. At top center is the open cluster/emission nebula complex NGC-2174/5. Near bottom center is the faint emission nebula IC 2162. Left inset: An enlargement from September 12th showing Halley's Comet. Right inset: An enlargement from September 14th showing two days' worth of Halley's motion against the starry background. All photos by Alfred Lilge, who used a 6.85-inch f/3.5 lens, 098-04 emulsion, and a 30-minute exposure. Above: On August 23, shortly after Halley became visible in the morning sky after solar conjunction, Jack B. Newton photographed it using a 16-inch f/5 reflector, hypersensitized TP 2415, and an 18-minute exposure.

As 1986 begins, Halley's Comet continues to brighten as it moves closer to its perihelion date in February. The comet will offer fine viewing prospects when the Moon doesn't interfere with sky darkness. December's observing window, described last month, will be much longer than January's, however. The message in January is "get out and observe Halley early in the month."

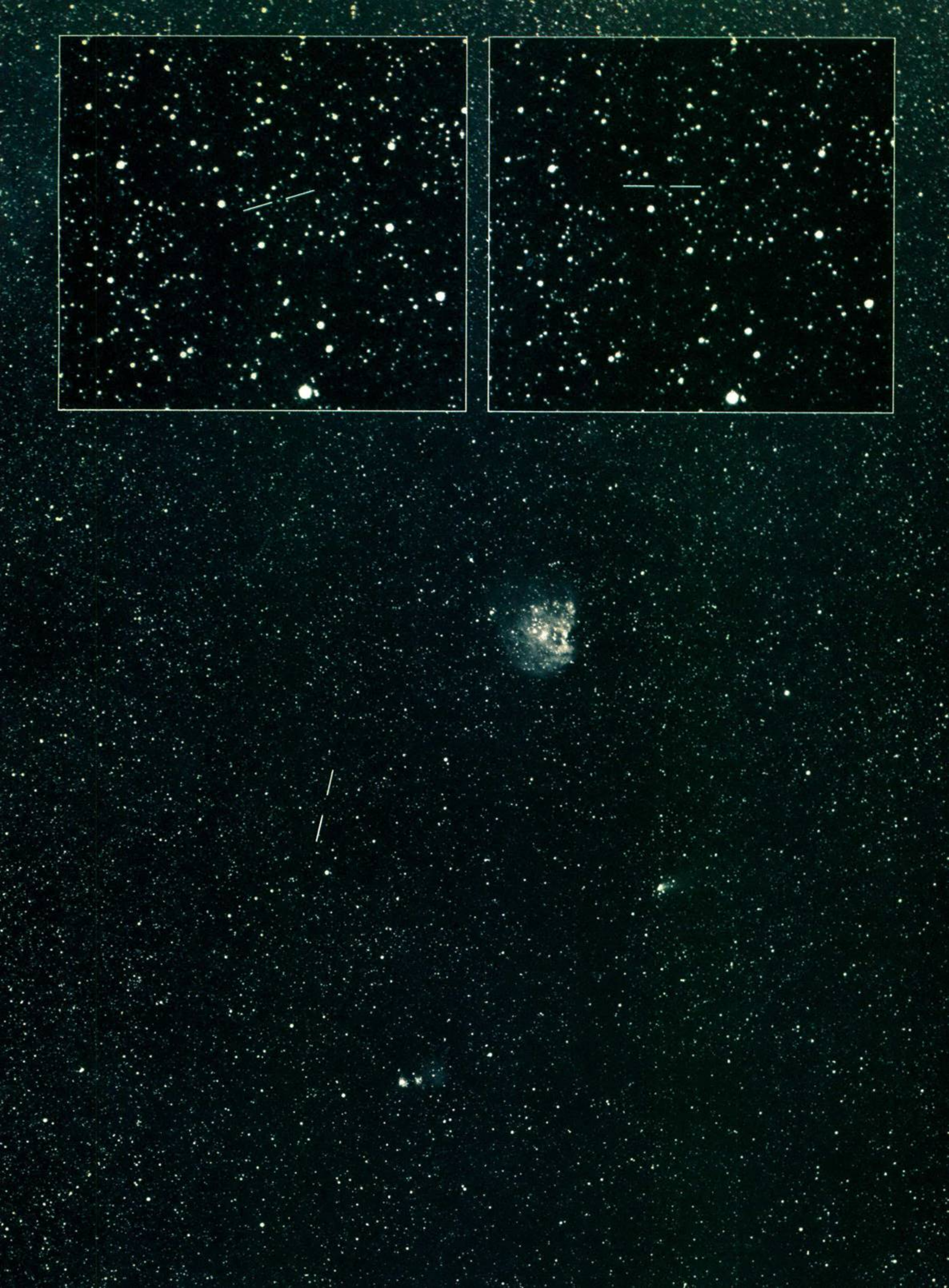
This shortening of good observing time is due not only to the Moon's interference, but also because Aquarius — the section of sky that contains Halley during January — rapidly sinks into evening twilight during the month. Despite all this, prospects for finding the famous celestial visitor early in January are good for two reasons: Halley's motion across the sky is slow and, more importantly, it may shine brighter than seventh magnitude — bright enough to spot in any telescope or binoculars.

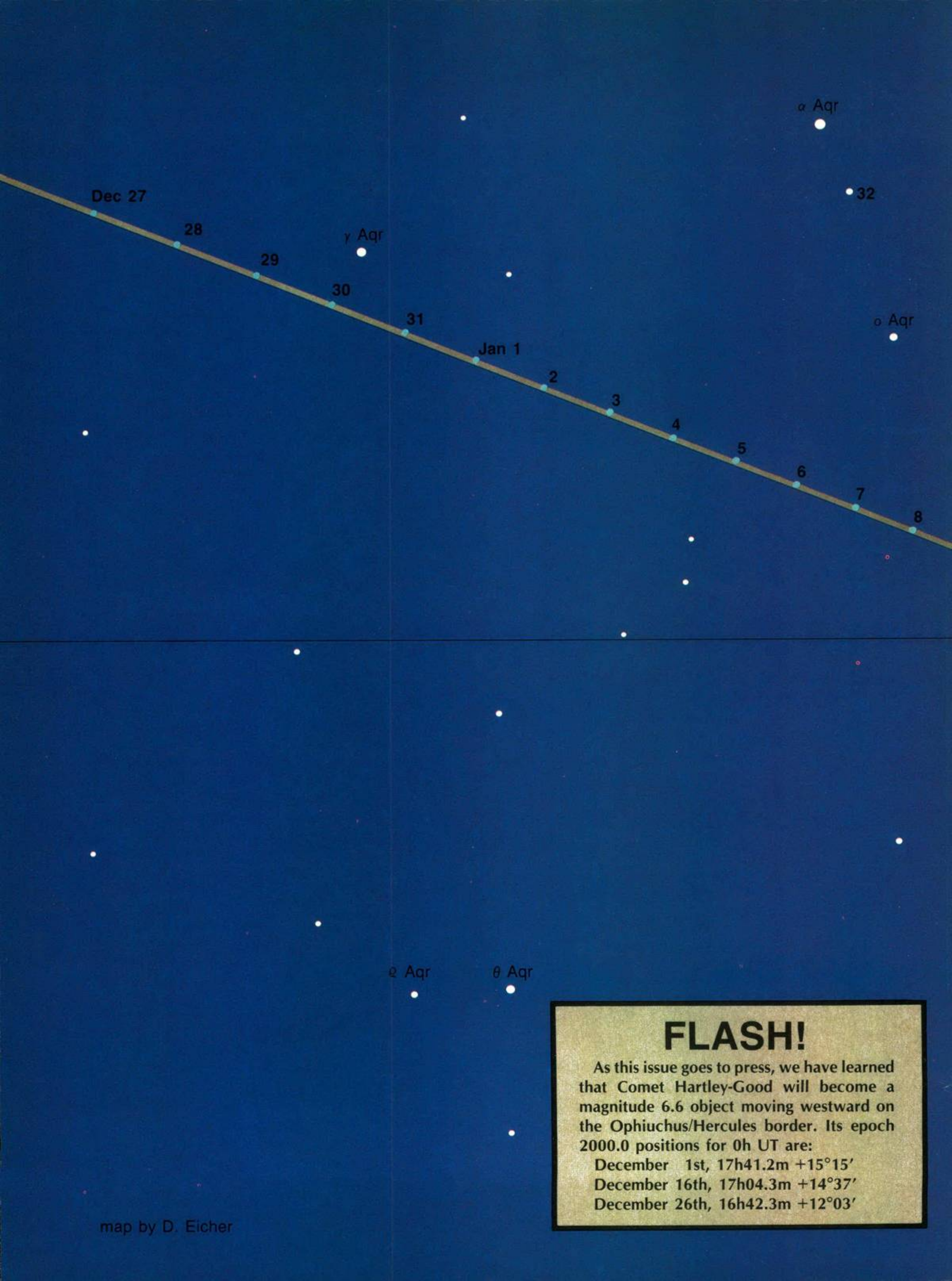
Halley from the Backyard: A Recap

Before discussing Halley's magnitude and whereabouts during January, let's recap what's happened so far. After emerging from a conjunction with the Sun, Halley's Comet became a dim, nearly stellar object in the August morning sky. Although very few observers — amateur or professional — saw the comet shortly after solar conjunction, it reportedly shone at fainter than 15th magnitude and was only a few arc-seconds across. The comet looked like a very faint, nearly stellar planetary nebula. The middle two weeks of August, when the Moon was between New and First Quarter, offered the best chance for spotting Halley. But even for observers equipped with large telescopes and blessed with a clear, transparent sky, August viewing was limited — the comet barely had time to rise high enough to be observed before morning twilight began. Because of the heavily-stacked odds against seeing such a faint object, the bulk of Halley watchers during August were professional astronomers.

By September, however, things were considerably better. Halley rose much higher in the sky before dawn and its position among the stars of Taurus — lodged between the Hyades and Pleiades clusters — made its approximate position obvious even to beginning sky watchers. Early in September, Halley's Comet was noticeably larger than in August; at around 14th magnitude, it was bright enough to spot with large backyard telescopes. Instead of looking like a weak, star-like planetary nebula, Halley's Comet now resembled a typical 1′ diameter NGC galaxy — definitely an improvement.

During the first two weeks of September, thousands of amateurs all over the world got their first view of Halley's Comet — undoubtedly a treasured moment for each of them. I remember my first look at the comet: I saw Halley at 10:13 UT on September 12th using the 42-inch f/16 reflector at Lowell Observatory's Anderson Mesa station. Even in a large professional telescope, Halley didn't look too impressive. But as I looked in the eyepiece for the first time, a chill ran up and down my spine. The comet seemed to be about 1.3′ across and slightly brighter than 14th magnitude. (The next night, Lowell astronomer Bob Millis photometered Halley and derived a V magnitude of 14.05.) The comet, lying in a field containing several bright stars,

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map by D. Eicher

FLASH!

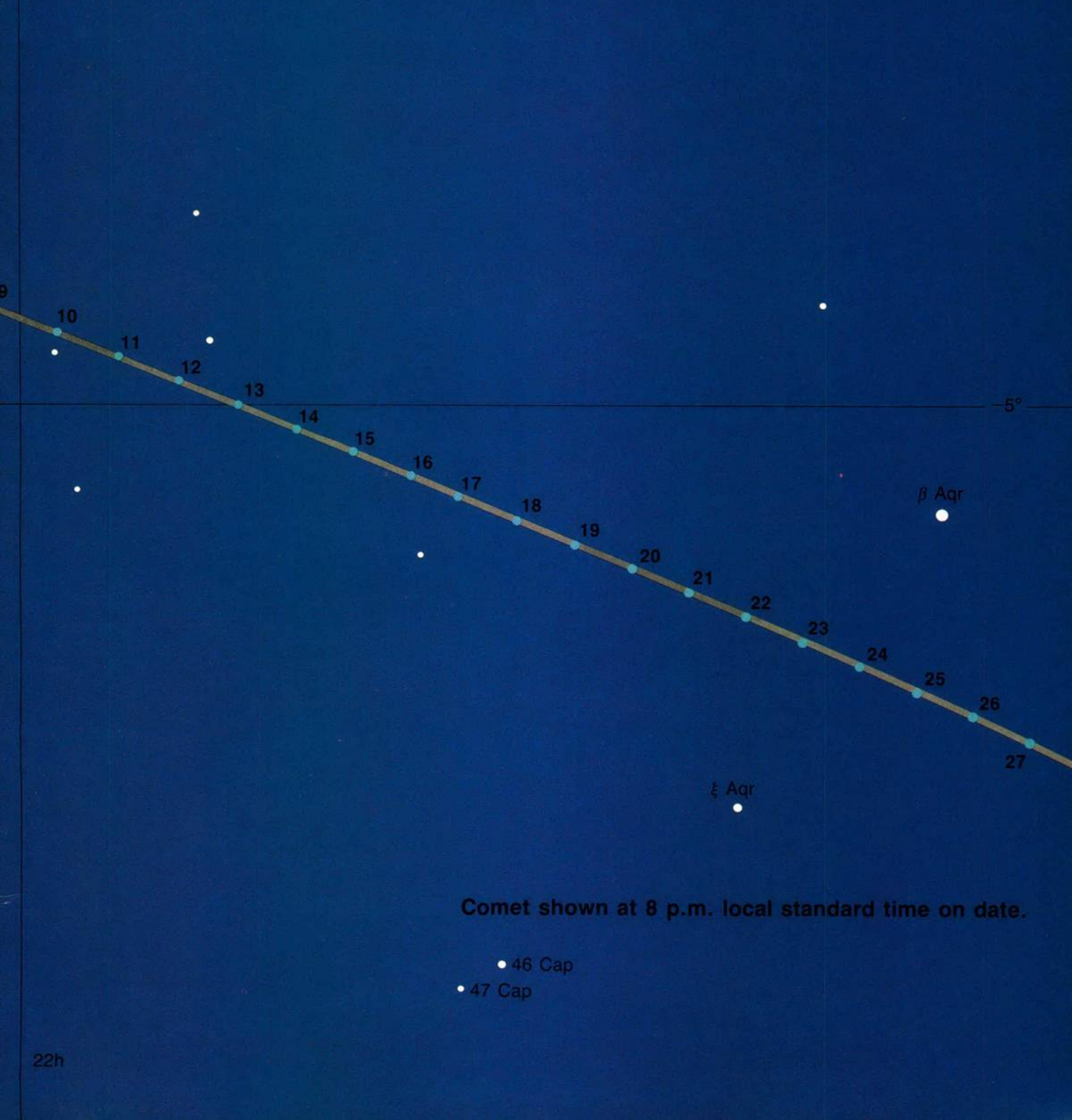
As this issue goes to press, we have learned that Comet Hartley-Good will become a magnitude 6.6 object moving westward on the Ophiuchus/Hercules border. Its epoch 2000.0 positions for 0h UT are:

December 1st, 17h41.2m +15°15′
December 16th, 17h04.3m +14°37′
December 26th, 16h42.3m +12°03′

Where to Find Comet Halley

January, 1986

(See the October issue, page 11, for our wide-field finder chart.)


Comet shown at 8 p.m. local standard time on date.

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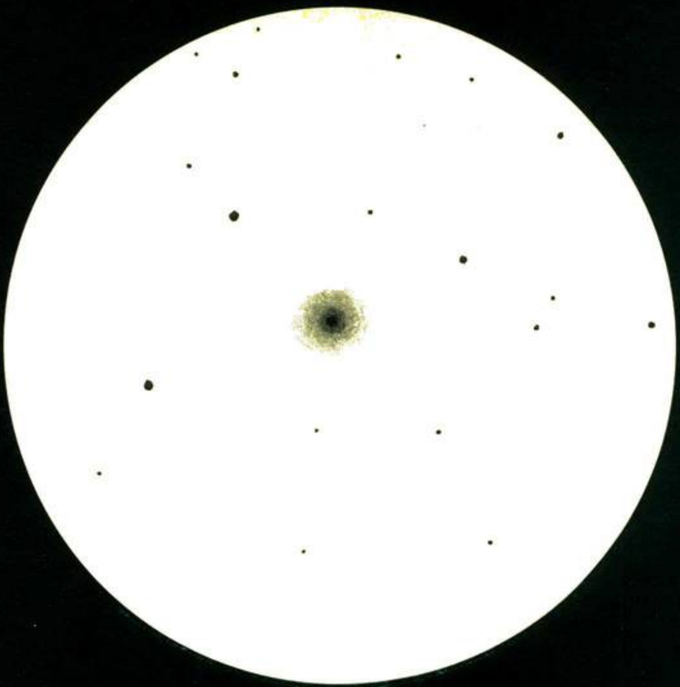
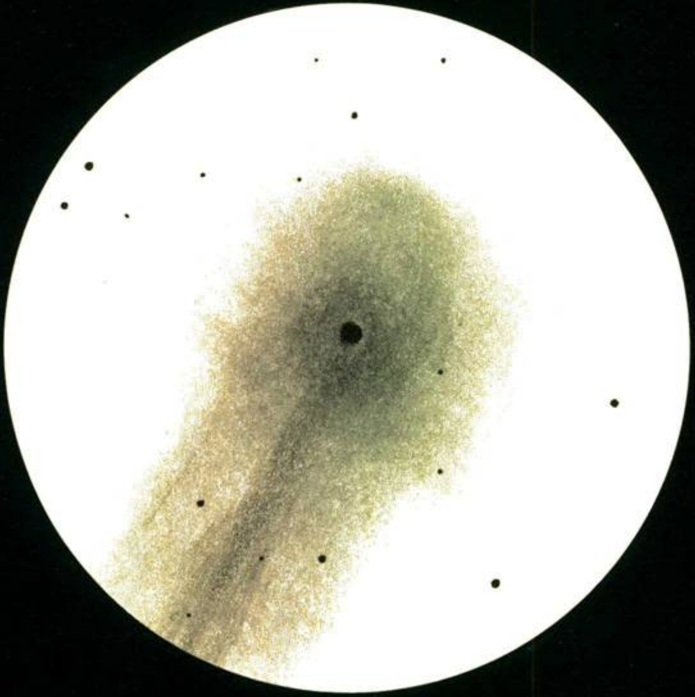
Comet Halley

sketched using Lowell Observatory's 42-inch f/16 Cassegrain reflector at about 400x on 10:13 U.T., September 12th. The comet appeared small and round, and had a 75″ low surface brightness coma and a tiny, relatively bright nucleus. Its estimated brightness was magnitude 13.8.

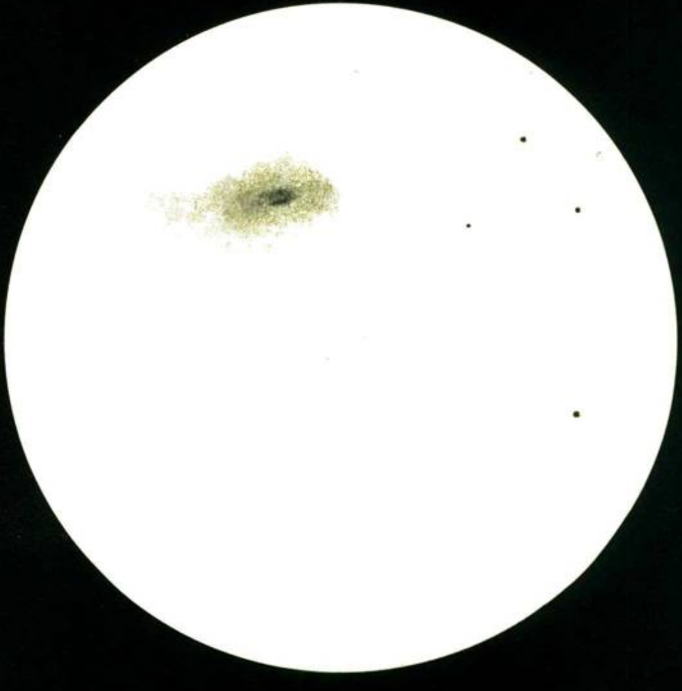




Comet Giacobini-Zinner

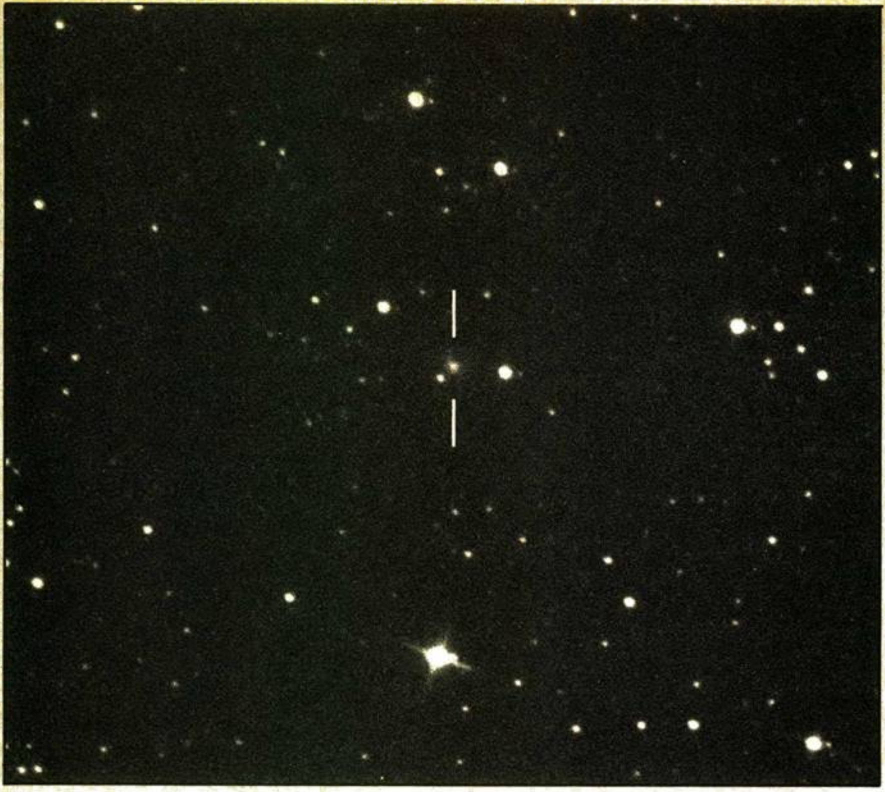
sketched using Lowell's 42-inch f/16 reflector at about 400x on 10:05 U.T., September 12th. At an estimated magnitude 8.5, Comet G-Z appeared far brighter than Halley. The coma appeared large and bright, covering the entire field of view with a soft glow. G-Z's nucleus was an intensely bright spot, and the fairly dim, wide tail was over a degree long.

All sketches by David J. Eicher



Comet Hartley-Good

sketched on 8:40 U.T., September 14th — three nights after its discovery — with Lowell's 24-inch f/15 Clark refractor. Comet H-G appeared like a 12.5 magnitude galaxy, an oval, elongated blur of smeary light. The nucleus was bright and off-center in the dimly glowing coma.



During September, Halley's Comet brightened to within the reach of backyard telescopes — about 14th magnitude. Michael O'Neal photographed it on September 14th using the 30-inch f/6 reflector at Stony Ridge Observatory in California. The exposure on 103a-F film lasted 30 minutes.

appeared about 75 seconds of arc in diameter. The coma had a very low surface brightness; the nucleus was very small and bright by comparison, and perfectly centered in the coma. I sketched the object, but it didn't look like much. I finally left the dome at 3:50 a.m. local time feeling cold and exhausted, but remarkably satisfied — I had seen Halley!

At press time late in September, Halley's Comet lay in Taurus, moving toward Aquarius; it is shining between magnitudes 13.5 and 14.0 and measures between 1′ and 1.5′. The upshot of September's observations is that Halley's Comet is considerably fainter — close to two full magnitudes — than originally predicted by the International Halley Watch. Could Halley become a flop, disappointing both the public and the astronomical community? Or will it brighten more quickly than originally thought as it gets closer to the Sun? By the time you read this, we should know the answers to these questions.

Observing Halley in January

Despite its dim beginning, Halley should appear quite bright as the New Year starts, at least when seen in binoculars. During January, Halley is an evening object, slowly moving from the Water Jar of Aquarius down to a point south of Beta (β) Aquarii. Finding Halley should be relatively easy with either binoculars or a finder telescope.

Taking into account that Halley has so far proven dimmer than everyone's predictions, it's difficult to estimate what the comet's brightness will be by January. Perhaps it's safe to say that Halley will shine at a minimum of seventh magnitude during the month, but it could be considerably brighter.

The best time to observe Halley in January is between the 1st, while the Moon is in the early morning sky, and the 15th, when the Moon reappears in the evening sky. After the 25th, the Sun will be too close to Halley's celestial position to permit viewing the comet. The cold, crisp evenings of mid-January are your last chance to see Halley's Comet before its closest approach to the Sun. The comet won't reappear until March.

What will Halley's Comet look like in January? It will probably be a seventh-magnitude glow with a coma measuring several arc-minutes across trailed by a diminutive tail. If you're able to find the field of stars around Aquarius' Water Jar, you'll have no trouble using the accompanying chart to pin down Halley with a finder scope or binoculars.

The Wild Cards: G-Z and H-G

At press time, two "wild card" comets are temporarily stealing the show from Mr. Halley's famous snowball. One of these, Comet Giacobini-Zinner, is a periodic comet that is well-known to comet buffs everywhere. Giacobini-Zinner (or simply G-Z) became bright enough to see with binoculars in June 1985 and was observed by practically everyone with a telescope all summer long. G-Z moved quickly across the sky because of its close approach to Earth, reaching its peak brightness of magnitude 8.0 by late August. The comet had a large coma measuring over 10′ across, a brilliant condensed nucleus, and a tail at least 2° long. By early September, G-Z's motion had carried it within several degrees of Comet Halley's position in central Taurus. Observers who viewed both Halley and G-Z with backyard instruments during their passage were certainly pleased with G-Z, but seemed to be growing impatient with Halley.

During the early morning hours of September 11th, Comet Giacobini-Zinner became the first comet ever examined by a spacecraft — the International Cometary Explorer, or ICE (see page 6 of this issue). Although the results were less than stunning, scientists at NASA's Goddard Space Flight Center in Maryland were delighted: they'd flown a probe through the coma and it sent back plenty of "real-time" data that will be compared with data from the five craft destined for Comet Halley. Comet G-Z will remain visible on the outward leg of its journey, shining brighter than 14th magnitude up until early March.

But G-Z isn't the only comet that has upstaged Halley. During the second week of September, discoverer Hartley and co-discoverer Good found the new comet on an objective prism plate taken with the United Kingdom Schmidt Telescope in Australia. At the time, Comet Hartley-Good (1985l) — otherwise known as Comet H-G — was a 13th-magnitude object in Sculptor — bright and fast-moving because it was less than one astronomical unit from Earth. When I observed H-G on September 14th with the Lowell Observatory's 24-inch Clark refractor, it appeared to be magnitude 12.5 and was clearly elongated with a bright nucleus. At press time, nothing more was known about this object, but the prospects are tantalizing: it is on the inbound path of its orbit and could pass quite close to the Sun. If so, Comet H-G could brighten considerably and show up Halley during the first weeks of the year.

What's an observer to think of all this? Clearly, judging from its appearance in September, Halley could become a disappointment. It may ultimately peak at fourth magnitude (or even fifth!) and its tail certainly won't cover several tens of degrees. But in a telescope, it will still be a bright, first-class comet. Comet G-Z will stay visible until February or March, at least for owners of large backyard telescopes. And Comet Hartley-Good? It may well brighten to compete with Halley during the initial weeks of 1986. We'll simply have to wait and see. But whatever happens, with three comets visible in the sky, who can complain?

David J. Eicher

Last chance to beat

Telescope manufacturers traditionally schedule price increases shortly after the New Year — and 1986 promises to be no exception! We have already received word from several manufacturers that they cannot guarantee current pricing past December 31. That means that if you want to save up to 45% on a telescope and accessories, *right now* is the right time to do it!

Some telescope dealers have low prices, but no telescopes. At Ad-Libs Astronomics, we have low prices and hundreds of telescopes *in stock!*

And some dealers strip out important standard accessories, claiming they're optional and charging extra for them. At Ad-Libs Astronomics, we give you *every* standard accessory the manufacturer supplies.

So why wait for a telescope that may never be delivered (and which may be missing some parts if it ever does come?) We can ship *today* — and we include all standard accessories . . . eyepieces, finders, cases, *everything!*

And why pay up to $100 freight, as some mail order dealers charge? Our prices include *free freight,* except on credit card orders.

Want a good price on a Meade, Celestron, Edmund, or Bausch & Lomb telescope — one that comes with *all* accessories, *free freight,* and can be shipped *now?* We have what you want. Just look . . .

2080/LX3, with MCSO
Shown with optional
#36 hand control box

~~$3020.00~~

$1795

Meade
THE LEADER'S EDGE

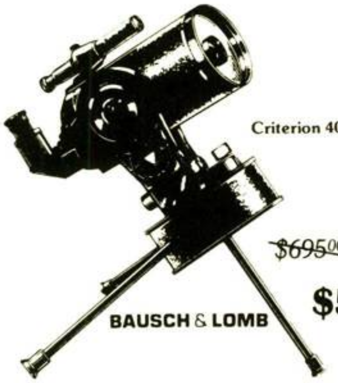
MEADE SCHMIDT-CASSEGRAINS

Our Meade Schmidt-Cassegrains include *every* standard accessory that Meade normally supplies, plus *free freight* (except on credit card orders). Just look at these bargains . . .

- **Meade 2045:** Compact 4" Schmidt-Cassegrain is telescope, spotting scope, and 1000mm telephoto lens — all in one! With motor drive, metal-clad case, 5 x 24mm finder, two eyepieces for 40x and 111x magnifications, coated optics, tabletop tripod, lifetime warranty, more! *$995 list* .... **for $595!**
- **Meade 2080:** All-purpose 8" Schmidt-Cassegrain suitable for visual and photographic observations both inside and outside the solar system. With electric worm gear drive, slow motion controls, carrying case, two eyepieces, wedge, field tripod, lifetime warranty, and more! *$2250 list* .... **for $1349!**
- 2080 with high transmission coatings $1439
- **Meade 2080/LX2, with MCSO:** Advanced 8" Schmidt-Cassegrain suitable for the serious amateur astronomer and astrophotographer. With multi-coated silver optics for 23% more light than standard coated optics, deluxe electric worm gear drive, 8 x 50mm finder, two Research Grade eyepieces, wedge, field tripod, deluxe latitude adjuster, lifetime warranty, and much more! *$2670 list* .. **for $1649!**
- 2080/LX2 with EMCG (enhanced mirror coatings group) for 12% more light transmission than standard coated optics $1599
- 2080/LX2 with high transmission coatings (10% more light than uncoated optics) $1549
- **Meade 2080/LX3, with MCSO:** The most sophisticated 8" Schmidt-Cassegrain available today! With multi-coated silver optics, deluxe worm gear quartz drive that operates from AC or DC, an 8 x 50mm illuminated polar reticle finderscope, two Research Grade eyepieces, piggyback camera mount, wedge, field tripod, lifetime warranty, and so much more! *$3020 list* .... **for $1795!**
- 2080/LX3 with high transmission coatings for 10% more light than uncoated optics $1695

Accessories for *2080/LX3*

- #36 drive control box $99.50
- #38 declination motor $99.50



Criterion 4000

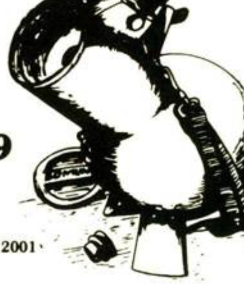
BAUSCH & LOMB

~~$695.00~~

$519

BAUSCH & LOMB/BUSHNELL

- **Criterion 4000:** This compact do-it-all 4" Schmidt-Cassegrain is a super value. It's a telescope, spotting scope, telephoto lens — all in one. With motor drive, carrying case, two eyepieces, 1200mm f/12 coated optics, tabletop tripod, lifetime warranty, more! *$695 list* .... **for $519!**
- For the highest light transmission of any 4" Schmidt-Cassegrain, the limited edition Criterion 4000/E adds enhanced aluminum mirrors to the standard 4000. *$725 list*............... **for $549!**



~~$299.00~~

$239

Astroscan 2001

EDMUND ASTROSCAN

- A 4⅛" f/4.2 rich field telescope with a 3° field of view for observing Halley's Comet now, effortless deep sky observing later! With 28mm (16x) eyepiece, rubber eyeguard, carrying strap, peepsight finder, altazimuth base, Sky Guide. *$299 list...* **for $239!**

Authorized Meade Dealer

~~$560.00~~

$369

Model 295

MEADE REFRACTORS

Our Meade refractors include *every* accessory Meade supplies, plus *free freight* (except on credit card orders). Just look at these bargains . . .

- **Meade 310:** A premium-quality 3.1" altazimuth refractor for the casual astronomer who wants breathtaking and hassle-free lunar and planetary views. With two 1¼" eyepieces, altazimuth mount, tripod, slow motion controls, 6 x 30mm finder, free freight, lifetime warranty. *$700 list* ..... **for $449!**
- **Meade 295:** An inexpensive 2.4" equatorial refractor with premium performance. With two .965" eyepieces, equatorial mount and tripod, setting circles, slow motion controls, 6 x 30mm finder, free freight, lifetime warranty. *$560 list* ..... **for $369!**
- **Meade 320:** A premium-quality 3.1" equatorial refractor at a far from premium price. Exceptional for planetary observing. With two 1¼" eyepieces, equatorial mount and tripod, setting circles, slow motion controls, 6 x 30mm finder, free freight, lifetime warranty. *$900 list*............... **for $599!**
- #784 single axis quartz motor drive and drive corrector for the #295 and #320 .... $164.50

All prices good through December 31, 1985, and limited to quantities on hand.

the price increases!

MEADE REFLECTORS

Our Meade reflectors include *every* accessory Meade supplies, plus *free freight* (except on credit card orders). Just look at these bargains . . .

- **Meade DS-10A**: A 10" f/4.5 Deep Space reflector superb for dark sky viewing and astrophotography. With eyepiece, #680 focuser, pedestal mount, setting circles, worm gear motor drive, free freight, lifetime warranty. *$1510 list* .... **for $999!**
- DS-10, without motor drive $869
- **Meade 826C**: Best all-around value 8" f/6 Newtonian reflector. Super for planetary/deep space visual and photographic work. With two eyepieces, 2" focuser with 1¼" adapter, 8 x 50mm finder, pedestal mount, leveling screws, latitude scale, latitude adjuster, setting circles, worm gear drive, free freight, lifetime warranty. *$1530 list* .... **for $999!**
- **Meade 645C**: Compact 6" f/5 Newtonian reflector great for deep space viewing and photography, high quality lunar and planetary observing. All the accessories and features of the 826C, above. Free freight, lifetime warranty. *$1370 list* .... **for $899!**
- **Meade 628C**: A 6" f/8 Newtonian reflector designed for superb high power lunar and planetary observing and photography, plus considerable deep space viewing. All the same accessories and features as the 826C, above. Free freight and lifetime warranty. *$1350 list* .... **for $889!**

Meade

THE LEADER'S EDGE

Model 6600

~~$1100.00~~

$699

- **Meade 6600**: A compact 6" f/5 Newtonian reflector loaded with features for all-around great performance. With two eyepieces, 6 x 30mm finder, adjustable-height tripod mount with slow motion controls, metal tube assembly and dust cover, latitude adjuster, setting circles, free freight, lifetime warranty. *$1100 list* .... **for $699!**
- **Meade 8800**: An 8" f/4.5 rich field Newtonian reflector designed for sensational deep space visual and photographic work. With all the features and accessories of the #6600, above. Free freight, lifetime warranty. *$1400 list* .... **for $899!**
- #784 single axis quartz motor drive and drive corrector for the #6600 and #8800 .... $164.50

CELESTRON TELESCOPES

Our Celestron reflectors and refractors include *every* accessory Celestron supplies, plus *free freight* (except on credit card orders). Just look . . .

- **Celestron Cometron CO-114**: A 4½" f/8.75 reflector that's great for the beginning astronomer who wants a general-purpose scope. With two .965" eyepieces, finder, Polaris equatorial mount, tripod, setting circles, slow motion controls, free freight, five-year warranty. *$600 list* .... **for $419!**

CELESTRON

C6

~~$1100.00~~

$729

- **Celestron C6**: Compact 6" f/5 Newtonian reflector designed for bright, wide-field deep space viewing and photography, plus sharp lunar and planetary views. With 26mm Plossl eyepiece, 6 x 30mm finder, adjustable-height tripod, Polaris equatorial mount, slow motion controls, metal tube assembly and dust cover, multi-coated optics, setting circles, free freight, lifetime warranty. *$1100 list* .... **for $729!**
- **Celestron SP-C6**: Compact 6" f/5 reflector has all the features of the C6, above, but adds a Super Polaris mount that includes a built-in polar axis finder and provisions for an optional Sky Sensor computer drive or dual axis drive corrector for long exposure astrophotography. *$1200 list* .... **for $799!**
- **Celestron Cometron CO-60E**: An inexpensive 2.4" refractor with enough quality built in to give you a lifetime of lunar and planetary observing enjoyment. With two .965" eyepieces, Polaris equatorial mount, tripod, setting circles, star diagonal, slow motion controls, 5 x 24mm finder, free freight, five-year warranty. *$500 list* .... **for $349!**
- Single axis pulse motor drive and drive corrector for the CO-114, C6, and CO-60E $134.50
- Single axis pulse motor drive and drive corrector for the SP-C6 .... $134.50
- Dual axis pulse motor drive and drive corrector for the SP-C6 .... $194.50
- Sky Sensor computer for the SP-C6 .... $379.00

Meade 11 x 80mm

~~$399.00~~

$229

CELESTRON

Super C8 Plus, with Starbright

~~$2750.00~~

$1749

CELESTRON SCHMIDT-CASSEGRAINS

Our Celestron Schmidt-Cassegrains include *every* standard accessory Celestron normally supplies, plus *free freight* (except on credit card orders). Just look at these bargains . . .

- **Celestron SP-C8, with Starbright® Coatings**: Newest version of the best-selling 8" Schmidt-Cassegrain, with silver mirrors for optimum light transmission. With equatorial mount, tripod, slow motion controls, carrying case, Plossl eyepiece, Starbright® silver mirror optics, lifetime warranty (Starbright® coatings guaranteed for 5 years), and more! *$1675 list* .... **for $1199!**
- SP-C8, uncoated $899
- SP-C8, special optical coatings $999
- Single axis drive for the SP-C8 .... $134.50
- Dual axis drive for the SP-C8 .... $194.50
- Sky Sensor computer for the SP-C8 ...... $379
- **Celestron Super C8 Plus, with Starbright® Coatings**: Top-of-the-line Celestron 8" Schmidt-Cassegrain designed for the serious amateur astronomer and astrophotographer. With Starbright® silver mirror optics, famous Byers deluxe worm gear drive, 8 x 50mm illuminated polar reticle finder, two premium eyepieces, wedge and field tripod, lifetime warranty (Starbright® coatings guaranteed for 5 years), and much more! *$2670 list* .... **for $1749!**
- Super C8 Plus, special optical coatings ... $1649

ACCESSORY BARGAINS

We have low prices on accessories, too! And we don't make you buy a scope to get those low prices, either! Just look at these examples . . .

• $220 Meade off-axis guider system	$149.00
• $120 Meade illum. reticle eyepiece	$79.50
• $150 Celestron illum. reticle eyepiece	$99.50
• $120 Meade 2080 tube balance	$89.50
• $120 Celestron C8 counterweight bar	$84.50
• $60 Meade Series 2 ortho eyepiece	$44.50
• $90 Celestron Plossl eyepiece	$67.50

Write or call today for our *free* discount price list showing your savings on the more than 70 telescopes and 500 accessories we carry, or send $1 for our complete catalog — the one our customers call the most complete and helpful one around.

BINOCULAR BARGAINS

Look at these astronomical savings . . .

• $399 Meade 11 x 80mm	$229.00
• $399 Celestron 11 x 80mm	$249.00
• $419 Meade 20 x 80mm	$239.00
• $419 Celestron 20 x 80mm	$269.00
• $600 Celestron Deluxe 20 x 80mm	$399.00

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ASTRONOMY

In Focus

Olson Too Pessimistic?

Sir / Edward Olson's article ("Intelligent Life in Space," July 1985) is provocative, but I feel it's somewhat too pessimistic. We should not interpret extraterrestrial events in terms of our terrestrial experience. That we are still doing so once again demonstrates the difficulty our species has keeping *itself* out of the quest for life in space. We assume that life forms follow selected evolutionary paths, but isn't it just as reasonable to assume that if our journey was delayed eons by clumsy or hostile environments, seemingly similar insignificant events — biologic or otherwise — might also accelerate progression. Since what we're searching for is the end result, we shouldn't hamper possibilities with the vagaries of our evolution into humans.

Anyone who'd work in my garden for a few days could not fail to appreciate the variety of terrestrial life forms. Some people hate all those weeds and bugs. I love them — they confirm over and over again that you can't stop life. You can put obstacles in it's way — and no one denies they abound. Still, there are only two possibilities: either we are alone in the universe or we are not. Humans are unequivocally unique, but I think that life — intelligent or otherwise — is probably not.

Dorothy C. Riedl
Quincy, IL

Interstellar Wanderlust

Sir / The article by Edward C. Olson in the July 1985 issue ("Intelligent Life in Space") was well reasoned and thought provoking. However, I believe an additional factor must be placed in the equation for the probability of extraterrestrial life in the galaxy to account for interstellar colonization.

The history of the species of intelligent life on this planet has been one of a compulsion to wander and settle inhospitable and dangerous new lands. Might this also apply to intelligent beings elsewhere in the Galaxy? Given a billion-year jump on us, one civilization could have seeded other star systems, their numbers growing exponentially as they spread thoughout the Galaxy? The number of intelligent civilizations would then be wholly unknowable, since they would grow rapidly even if only one civilization began to wander and colonize the stars. I wonder what fraction of intelligent civilizations are consumed by stellar wanderlust?

David Gardner
Los Angeles, CA

Hurray, Dolly!

Sir / I just completed my "Dobsonian Dolly Transport System" as described in your June 1985 issue.

Since I got my 13-inch Dobsonian, the skies have never looked better, but I've been plagued with a practical problem: the telescope is so massive that I needed help moving it the 200 feet to my observing site.

Last night, with the help of the dolly transport, I handled the whole procedure myself — a remarkable feat with a 150-pound instrument. I look forward to using the device this winter when low temperatures drive my wife (and other sane people) indoors. Author Terry Uselton's built-in chart table and eyepiece holder are a great help, too.

Thanks for publishing such a thoroughly practical idea. If there are any other Dobsonian owners out there who've been wondering about a dolly — go build one! It cost me only about $70, and I know it's going to double the enjoyment of my "light bucket."

Steven Forrest
Chaple Hill, NC

Summertime Blues

Sir / The summer season is great because it allows many observers their best opportunity to stay up late and get lots of observing done. But usually when you're out from 9 p.m. Saturday to 4 a.m. Sunday — the classic "all nighter" — funny things happen. The standard problems are having your telescope, star atlas, and ASTRONOMY magazine become drenched with dew, your neck and back feverishly aching, bones freezing cold (especially toes and fingers), eyes dried out and itching, and mosquitoes attacking en masse.

I can live with all of this for the sake of science, but sometimes I have other problems which are more disturbing. For example, big hairy spiders occasionally scuffle around the scope's tube and into my hair — for some reason, usually when I'm looking at the globular cluster M-30 in Capricornus. Then there are the times when low-flying bats sweep screeching by and nearly scare me to death. And at 3 a.m. begin the bizarre animal noises on both sides of me. Should I ready for attack with my red flashlight? Aaargh! It's only a raccoon — are they vicious? Maybe it's time to go get some sleep!

In spite of these setbacks, last summer's observing was tremendous. This astronomy bug has bitten me and I'm definitely hooked!

Frank Prendergast
Jamaica Plain, MA

Space Fans, Take Note

Sir / Where can I write to get color photos of each Shuttle crew?

Florence Jakubiec
Caledonia, Ontario

— The best place to start would be the Office of Public Affairs at the Lyndon Johnson Space Center, Houston, TX 77058.

Support Mt. Graham!

Sir / Since Percival Lowell first built an observatory near Flagstaff in 1894, Arizona has been world-famous for its astronomy. Following the selection of Kitt Peak as a national observatory in 1958, some of the largest U.S. telescopes have been built in Arizona.

But the future of astronomy in Arizona is now threatened. Our present observatory sites are not high enough to be competitive in submillimeter and infrared astronomy — the new direction of the science today — and optical astronomy is also jeopardized by light pollution from nearby cities.

This is why the University of Arizona's Steward Observatory is conducting a site-testing program and Environmental Impact Study on 10,700-foot Mt. Graham, the highest peak in the Pinaleno Mountains, 75 miles northeast of Tucson. This site is high enough to be above much of the water vapor in Earth's atmosphere — a requirement for submillimeter and infrared astronomy, since these wavelengths are absorbed by water vapor — and far enough away from the city lights of Tucson and Phoenix to be a viable dark-sky astronomy site for generations to come.

Mt. Graham is managed by the Forest Service, and they will make a decision whether to allow an observatory on the site. Their decision depends in part on public comment. If you wish to support the future of astronomy and an observatory on Mt. Graham, please write to the following:

Mr. Robert Tippeconnic
Forest Supervisor
Coronado National Forest
301 W. Congress
Tucson, AZ 85701

Congressman Jim Kolbe
1222 Longworth
House Office Building
Washington, DC 21505

Governor Bruce Babbitt
1700 W. Washington
Phoenix, AZ 85007

Congressman Morris Udall
235 Cannon
House Office Building
Washington, DC 21505

Senator Barry Goldwater
363 Russell
Senate Office Building
Washington, DC 20510

Senator Dennis DeConcini
328 Heart
Senate Office Building
Washington, DC 20510

Lauray Yule
Special Assistant
Steward Observatory
Tucson, AZ

Satellite Predictions

Sir / I placed an AstroMart ad in ASTRONOMY and through it contacted 10 others interested in observing satellites and sharing our data — thank you!

Some of our club members eavesdrop on satellites with shortwave radios. We can provide information on this for readers if they send us a SASE and $1 for copying costs.

There are thousands of good targets for observation. Cosmos' final stages (7x3 meters) are the most numerous; they are magnitude 3.5 to 4 tumbling objects. There are many science and astronomical payloads to see, too: OAO, OGO, Solar Max, IRAS, along with the Agena, Delta, Saturn, Scout, and Centaur final stages. I find the small Japanese payloads especially challenging.

The Shuttle can be seen 20° above my southern horizon at first magnitude. Whenever they launch into higher-inclination orbits, people north of my 36° north latitude can see the Shuttle also. NASA's Goddard Space Flight Center provides special Shuttle bulletins and a "Shuttle Mission Chart" to help you observe. For Shuttle and satellite predictions, write to Code 513, NASA GSFC, Greenbelt, MD 20771; for Shuttle mission charts and the "Satellite Situation Report" (a semi-annual publication which lists what's in orbit now and what has decayed), write to Code 120 at the same address.

Jim Hale
HCR 65 Box 261-B
Kingston, AR 72742

Behind the Scenes

In the Tail of a Comet

Less than two weeks ago, a spacecraft about half the size of a Volkswagen "Beetle" became the first man-made object to probe a comet. The flyby, accomplished by a spacecraft built and launched for an entirely different purpose, is a tribute to NASA Mission Engineer Robert Farquhar. Its success is all the sweeter because the mission was an American space "first." However, we Americans shouldn't crow too much because the *real* American mission to a comet got lost somewhere between NASA, Congress, and the OMB. Perhaps we'll be doing well enough if we've learned not to muff priceless scientific opportunities — like NASA's Halley flyby — in the future.

National considerations aside, ICE opens a very exciting era in comet exploration. In the coming year, the Russian Vega, the European Space Agency's Giotto, and the Japanese Suisei spacecraft will all encounter Halley. We'll be covering these missions, too, along with the inevitable revolution in cometary physics that will follow.

This month we also address a question that should interest those who, like myself, remember the Moon walks and Moon rocks. (Was 1969 *really* that long ago?) At the time, those rocks seemed like the most important rocks in the world. But what happened to them? Our second lead story answers that question. Since it looks as if it's going to be quite a while before anyone goes back to the Moon, it's good to know that they're in good hands.

A side note on Moon rocks: the article states that 2% of them are "being used for display and educational purposes." That piqued my curiosity — where are those rocks? While I was in Washington, D.C. for the ICE flyby, I found — and touched — one of them at the Air and Space Museum. It's near the main entrance, cast into a slab of plastic, and watched over by a guard. Anybody who wanted to see the rock had to wait in line. The exposed surface is polished to a shiny, almost metallic, look from being rubbed by millions of fingers.

Five more Moon rocks (better ones, really) reside in little plastic cases in the Moon exhibit on the second floor of the National Museum of Natural History. Since there was no waiting line to see *those* rocks, I got a satisfyingly long look at them. They come from five different selenological eras, which the exhibit materials explain. And what do they look like? Well, they're rocks, and they look like rocks.

Sincerely,

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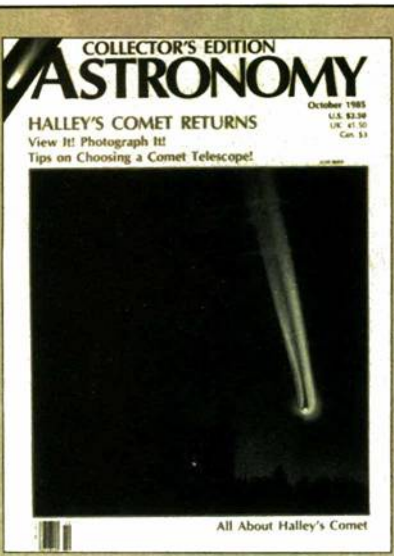

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Discovering Binocular Astronomy

by
David H. Levy

Ronald Royer

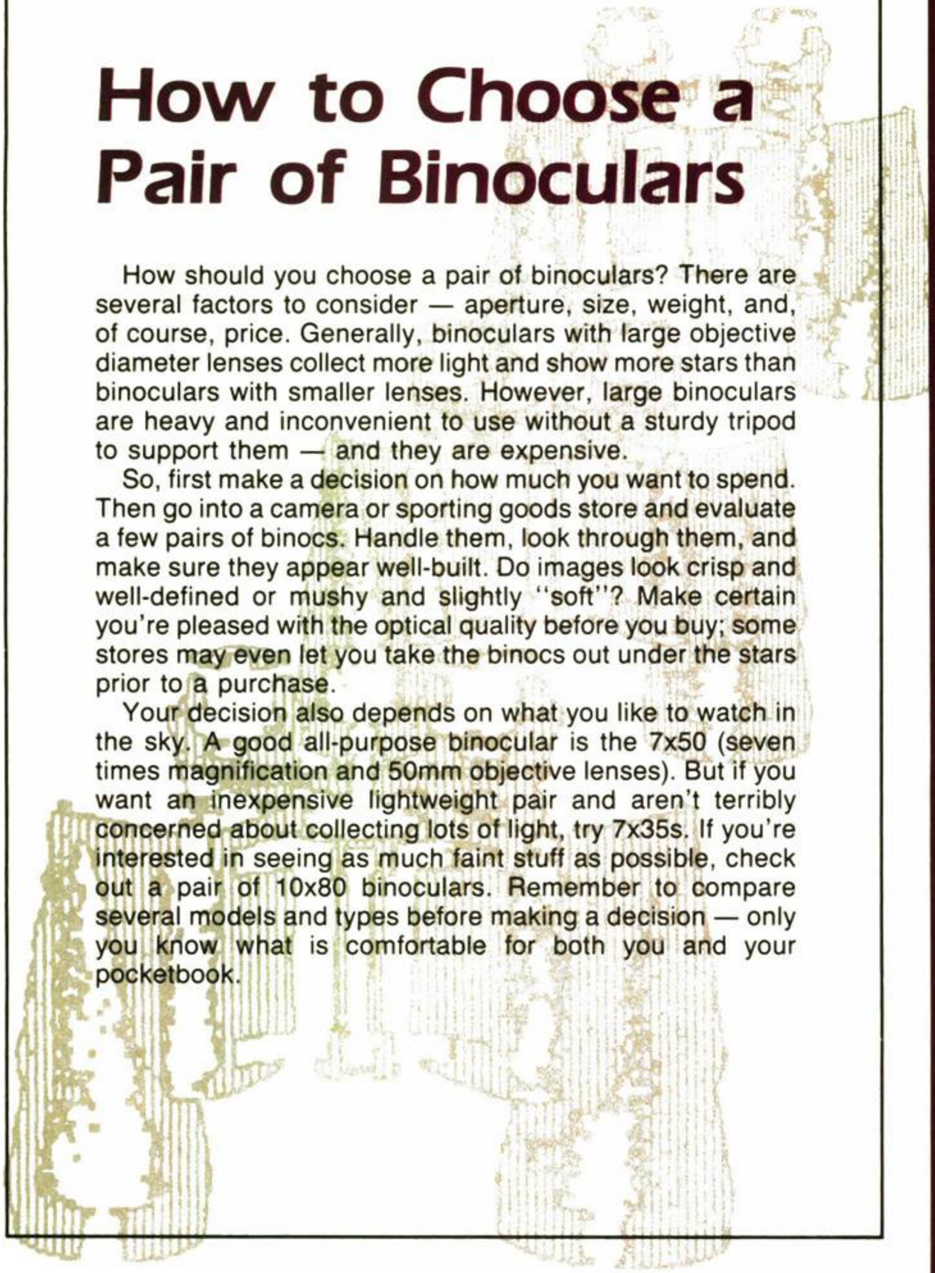
Binoculars are probably the most versatile instrument ever devised to observe nature. They can start the day by showing you birds flocked in a tree, herons on a lake, moving traffic on a bridge, or a critical baseball play, and end it with a silent look at the stars. Each of these views offers you the chance of discovery, of a new interest, of learning something new about our environment. Indeed, many of us began our love for the stars gazing through binoculars.

Inexpensive and available practically everywhere, binoculars have a wonderful ability to show us new things in the sky. They can help us discover comets, for example, or the unexpected behavior of variable stars. And if we expand the definition of discovery to include things which are new only to us as individuals, the list can go on and on: we can "discover" spots on the Sun, the phases of Venus, craters on the Moon, the satellites of Jupiter, or the motion of asteroids, to name just a few.

Even for beginners, the first view through binoculars tells much about the sky. A look at the Milky Way shows that it isn't a continuous band of light, but a vast collection of countless individual stars. Look at the planets Mars, Jupiter, or Venus and discover how their positions among the stars change from night to night. Look carefully at small groups of stars within the constellations and you'll discover new sights; for instance, not far from Albireo at the foot of the Northern Cross is a curious asterism that looks like a coathanger. It's a little too faint for the unaided eye and it overfills a telescope's field — but it's ideal for binoculars.

Binocular astronomy isn't simply a

How to Choose a Pair of Binoculars



How should you choose a pair of binoculars? There are several factors to consider — aperture, size, weight, and, of course, price. Generally, binoculars with large objective diameter lenses collect more light and show more stars than binoculars with smaller lenses. However, large binoculars are heavy and inconvenient to use without a sturdy tripod to support them — and they are expensive.

So, first make a decision on how much you want to spend. Then go into a camera or sporting goods store and evaluate a few pairs of binocs. Handle them, look through them, and make sure they appear well-built. Do images look crisp and well-defined or mushy and slightly "soft"? Make certain you're pleased with the optical quality before you buy; some stores may even let you take the binocs out under the stars prior to a purchase.

Your decision also depends on what you like to watch in the sky. A good all-purpose binocular is the 7x50 (seven times magnification and 50mm objective lenses). But if you want an inexpensive lightweight pair and aren't terribly concerned about collecting lots of light, try 7x35s. If you're interested in seeing as much faint stuff as possible, check out a pair of 10x80 binoculars. Remember to compare several models and types before making a decision — only you know what is comfortable for both you and your pocketbook.

watered-down version of the "real" telescopic thing. It's a completely absorbing activity all its own.

Choosing Binoculars

What type of binoculars should you get? There are two basic designs — the Porro prism and the roof prism. The Porro prism model is the one with the classic "stepped" or "dog-leg" shape, while the roof prism design is usually more compact and has a "straight through" appearance.

For stargazing, prism type and style are not as important as the diameter of the objective lenses and its relationship to magnification. Since the night sky is dim, you need large objective lenses — the larger the objectives, the more light they'll collect.

Magnification is also important. When you divide the magnification into the diameter of the objective lens, you get a number which is the diameter in millimeters of the exit pupil — the bundle of light rays leaving the binoculars and entering your eye. Obviously, you want binoculars that put as much light into your eye as it can accept. Therefore, look for binoculars which deliver an exit pupil large enough to fill your dark-adapted iris. How big is this? For most people, a fully-opened iris has a maximum diameter of 5 to 7 millimeters (generally, the older you are the smaller the maximum opening).

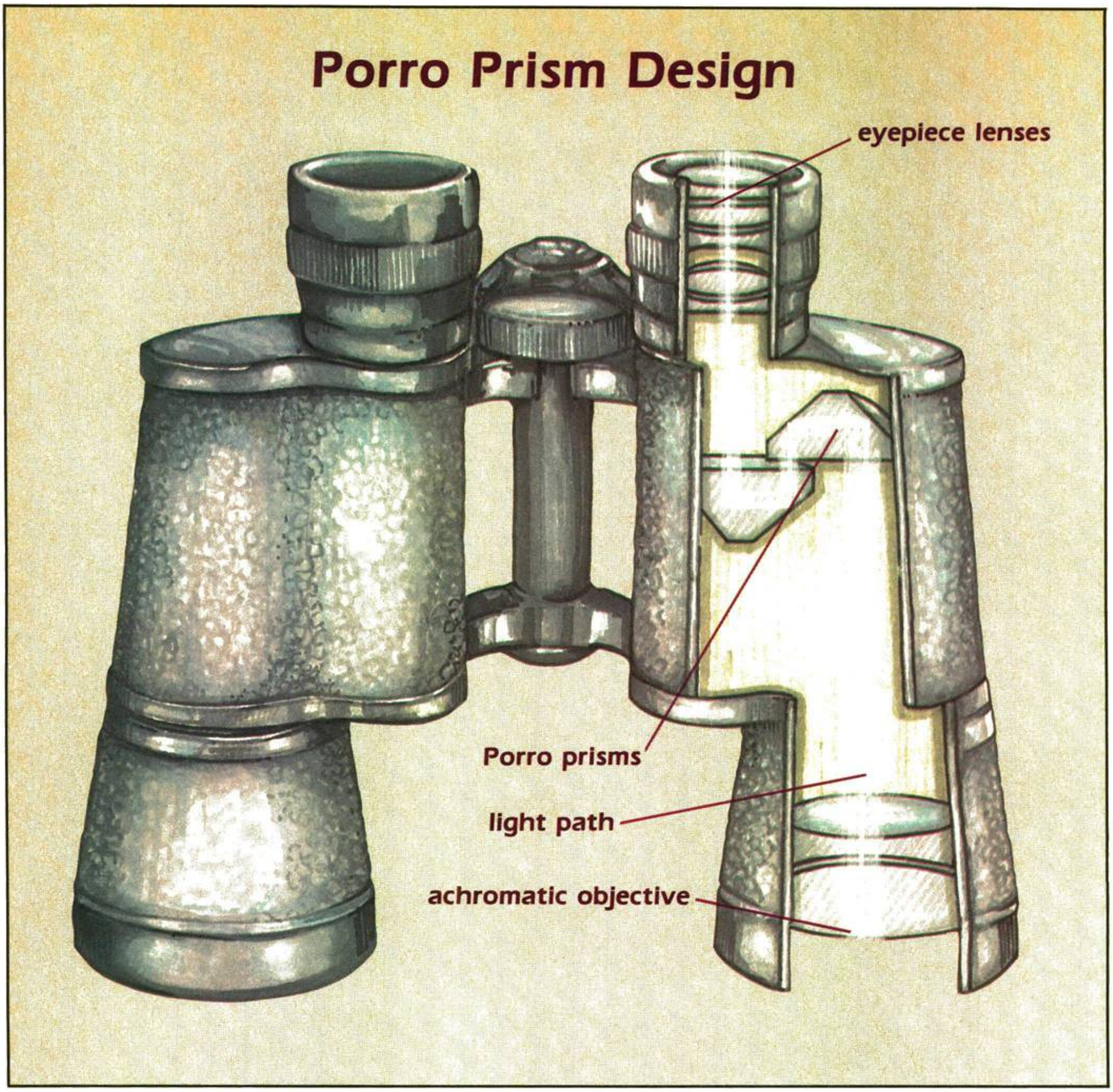
This is why 7x50 binoculars have long been such a favorite for astronomical observing. They have objective lenses 50mm across — large enough to collect plenty of starlight — and the magnifying power of 7x delivers a 7.1 millimeter exit pupil. In addition, 7x50s are small and lightweight enough to use for hours.

What's best for you? Count up your

Moore Observatory

Discovering Comets

With their wide fields of view, binoculars are extremely well-suited for comet hunting — sweeping the morning and evening sky in search of "dirty snowballs." Since most new comets are relatively faint, large binoculars mounted on sturdy tripods work best for comet hunting. You may spend many hours slowly sweeping along the ecliptic (remember to have a star atlas handy so you don't confuse potential comets with galaxies or nebulae!), but one day this dedicated searching may indeed pay off in a discovery.



pennies, decide what you're willing to spend, visit several camera stores, look over as many different brands as you can, and *handle every one of them*. Don't be stampeded by a clerk impatient to make his sale and move on. Ask yourself: How do the binoculars feel? Is the balance right? Is this model too heavy? Does the construction look cheesy? Do my fingers reach the focusing device easily — and does it work smoothly? Then check optical quality: Do bright lights have colored flares around them? Do straight lines bend near the edges of the field of view?

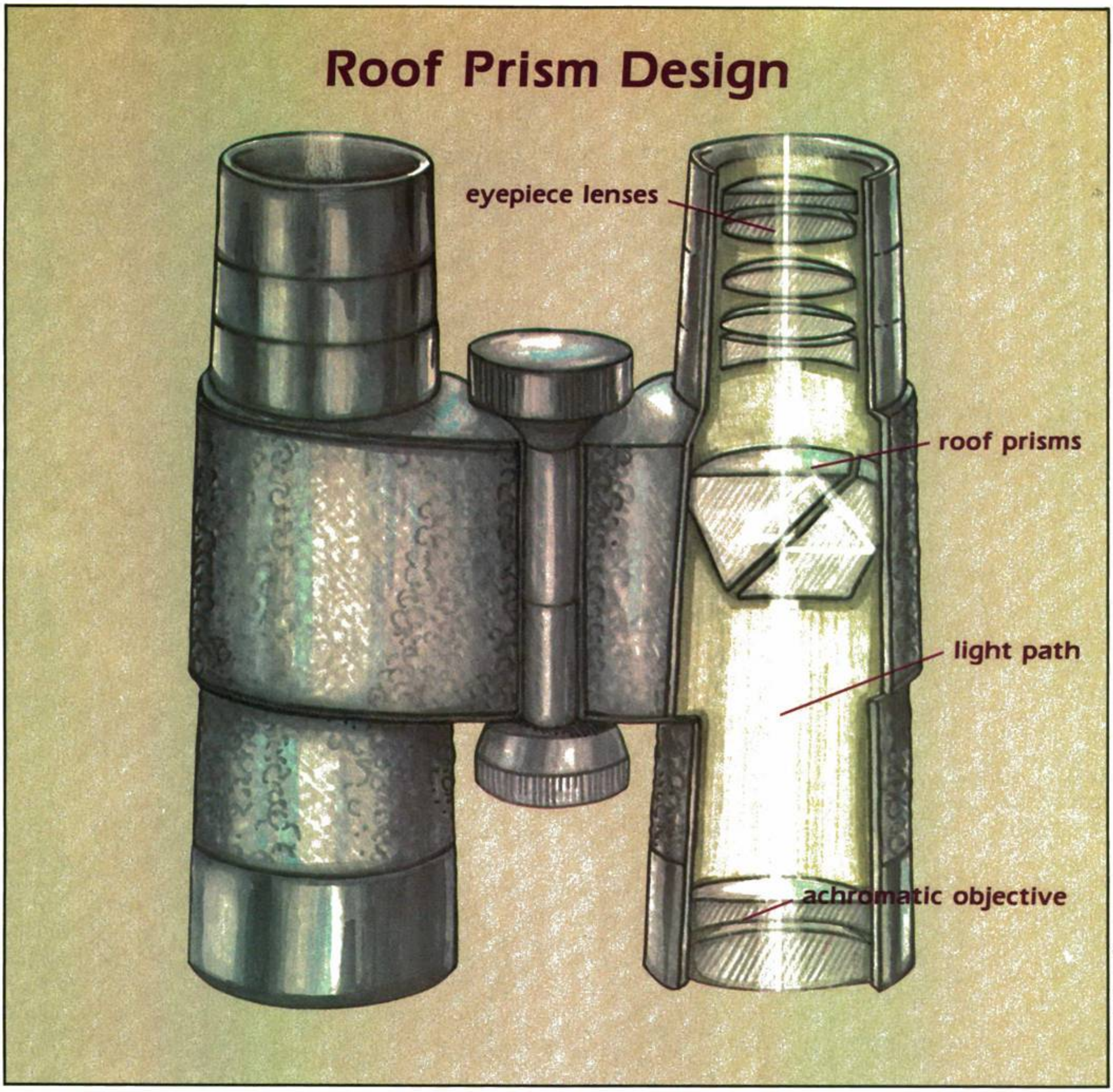
In the end, be satisfied that you've found the best for the money — and be prepared to stretch the budget a little. After all, if you buy good binoculars, you'll be using them the rest of your life.

Now that you have your binocs — what are you going to do with them? For the first few clear nights, take a lawn chair into the backyard, cover yourself up with a blanket or sleeping bag, and simply scan around the sky to see what's there. Notice how many more stars you see in the Pleiades — and how many little stars there are between Auriga and Gemini. Isn't that the Double Cluster between Perseus and Cassiopeia? And look — down by the horizon, Jupiter and its four little moons are visible!

When you go indoors later, spend time with a map to scout an observing site as far from city lights as you can get to easily. And now's the time to consider getting that top-notch star atlas, if you don't have it already.

Searching for Comets

After you've spent a number of clear nights just looking here and there, you might want to organize your discovery —



Illustrations by Pat LaBrecque

one way of doing this is getting into comet searching. You might think it highly unlikely that you could discover a new comet with a pair of binoculars. This isn't necessarily true, however. Between 1948 and 1960, observers at the Skalnate Pleso Observatory in Czechoslovakia discovered 16 comets with a pair of 100mm binoculars. Each comet took them an average of 100 hours' searching.

For comet hunting, binoculars' greatest asset is that they show a large chunk of sky in a single field of view. Couple this with the knowledge that a new comet is most likely to show up only in certain parts of the sky and you significantly increase your chances of finding a comet.

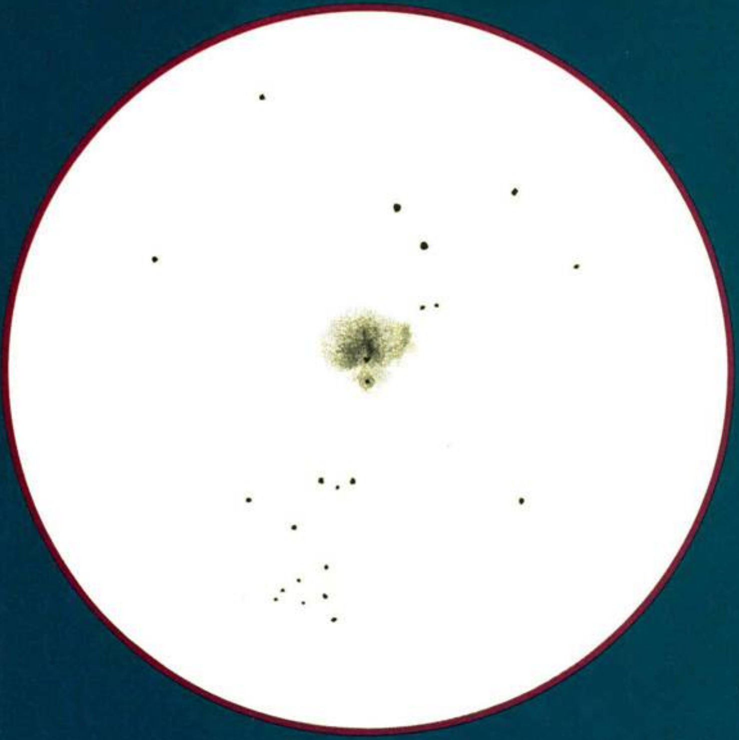
Comets approaching from behind the Sun may stay invisible until perihelion, when they could suddenly appear in the post-dusk or pre-dawn sky. These comets are beyond the reach of professional telescopes or satellite observatories, whose main targets lie far from the twilight sky. This makes comets fair game for backyard observers, and every once in a while one comes along that's bright enough for small binoculars.

The key to discovering a comet is dogged persistence. Be out every clear evening, every clear morning. And be careful to check those parts of the sky which moonlight has just vacated. This means searching the dusky sky of evening two days after Full Moon and the predawn sky just before New Moon. These both offer the highest chances of containing a brand-new comet. Look slowly and carefully as you move from one binocular field to the next, staying as close to the horizon as you can. After sweeping one section of sky, scan backwards, one field

Gerard de Vaucouleurs

Discovering Novae

The Latin word *nova* means "new star" — about 10 or 15 novae flare to many times their normal brightness each year. These are actually old objects ejecting large amounts of heat and light because of runaway hydrogen burning. It's entirely possible to find a nova with binoculars since their large fields of view permit scanning vast areas of sky. Before attempting to discover one, however, you should first memorize the patterns of bright stars in selected areas you want to scan. Do this by observing the constellations frequently and checking them against star maps. If you see a new object in the area, you may have discovered a nova.



Sketches of M-42 by David J. Eicher

higher. Check any possibles against a good star atlas, like the *Sky Atlas 2000.0*, and be skeptical. Excitedly phoning all your friends to report a "new comet" — which turns out to be an ordinary little nebula — is a *faux pas* they'll delightedly retell for years to come.

You may or may not discover a comet with your binoculars, but even if you don't, you'll quickly become a very keen observer of the sky.

Find a New Star!

Binoculars are also ideal instruments for finding novae, exploding stars in our Galaxy. An explosion in certain types of stars causes a normally faint star to brighten so much that it appears like a "new star." To hunt for novae, search areas near the Milky Way (where novae are most common) and learn the stars in those areas as well as you know the houses on your street. Choose a few constellations whose stars you can learn down to sixth or seventh magnitude, and search these areas every clear night. The better you know the stars in your area, the greater your chance of discovering the interloper that upsets the regular pattern.

This may sound like a hopeless task, but bear in mind that English amateur astronomer George Alcock has discovered five novae in the Milky Way using no instrument more sophisticated than his binoculars! How did he do it? Simple perseverance — and knowing several regions of the sky like his own backyard.

Variables: Stars that Flicker and Fade

Novae are actually a special subclass of variable stars, the catch-all name for a type of object that offers many discovery possibilities. Some variable stars are so bright you can observe their changes without any optical aid. But with binoculars, there are thousands of flickering stars to keep an eye on.

A bright variable star is Mu (μ) Cephei, one of the reddest stars in the sky. Aptly nicknamed the "Garnet Star" by the great observer William Herschel, Mu Cep varies in light output with no rhyme or reason. Varying from a maximum of magnitude 3.6 to a minimum of magnitude 5.1, Mu Cep is easily visible even from a slightly light-polluted urban area. The star has no known period, and attempts to find long-term or superimposed multiple periods have been inconclusive. So every time you watch this star, you're experiencing an unknown.

Many variable stars are bright enough for small binoculars only at their greatest light output. These long period stars vary over several months and are often invisible with anything less than a 6-inch telescope. Mira, also known as Omicron (ο) Ceti, varies from about fourth to ninth magnitude over a period of nearly a year. In addition, astronomers don't know how bright Mira will become at each maximum — it once rose to second magnitude! Chi (χ) Cygni, a long-period variable star in Cygnus, usually rises to fifth magnitude at maximum and adds an extra star to the Northern Cross.

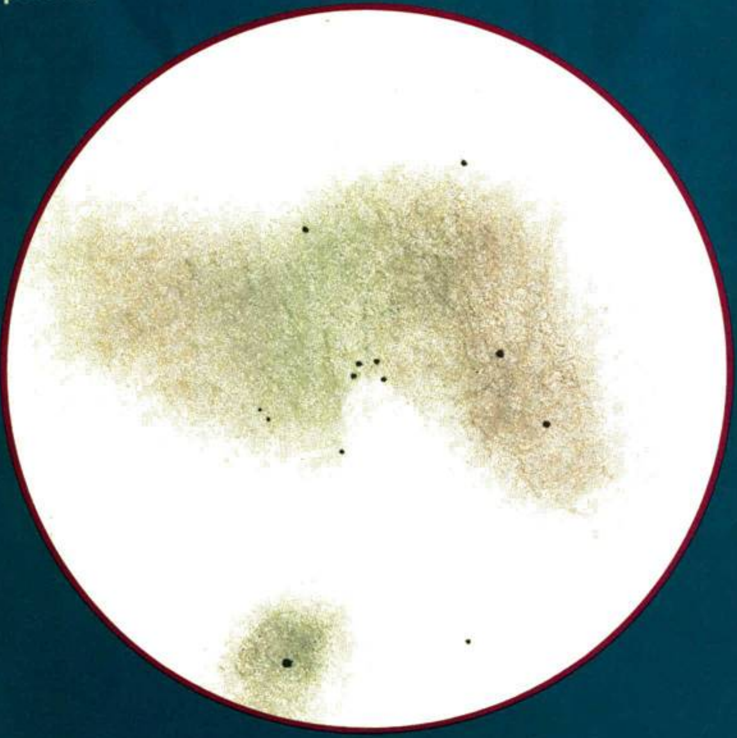
Double, Double, Toil and Trouble

Most stars in the sky come in pairs or multiples; our solitary Sun is something of an exception. Double and multiple stars usually require the high resolution and magnification of a telescope to be split, but some of the prettiest are visible with just binoculars. Albireo, Beta (β) Cygni, has been mentioned already as a finder star for the Coathanger, but it's also a blue

Binoculars vs. Telescopes

Why should you settle for observing with a pair of binoculars when you could use a backyard telescope instead? There are three reasons: binoculars are inexpensive and portable, they collect as much light as small telescopes, and their wide fields of view often help in observing various objects (like all of M-42) rather than hindering, as shown by this illustration.

8-inch f/10 SCT at low power



Brian Skiff

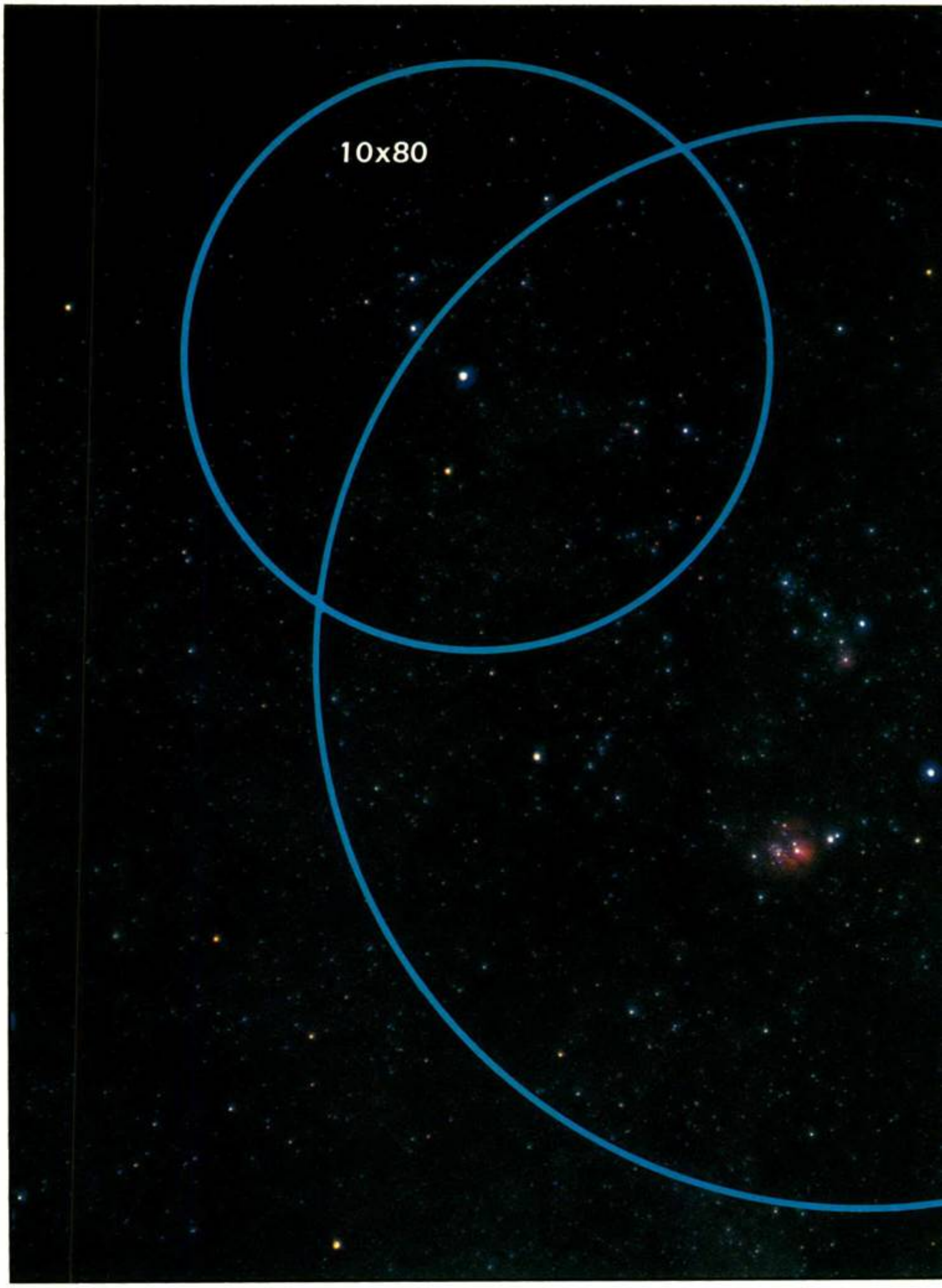
Discovering Variable Stars

It's very difficult to actually discover a variable star. To do so requires accurate photoelectric photometry of a star no one has yet scrutinized. But you can discover thousands of variable stars in the sense that *you* are observing them for the very first time. There are many types of variables — bright, faint, irregular, eruptive — all of which are visible in binoculars. Try making a sketch of the relative brightnesses of stars in the field of a variable, then observe the star later and compare how its brightness has changed.

Jay Anderson

Discovering Double Stars

Double stars are lots of fun to observe: they're colorful, they come in many brightnesses and separations, and they're scattered all over the sky. Some night when you want to relax, take a pair of binoculars outside and simply scan across star fields. If you look for a while, you'll undoubtedly come across many pairs of stars. Remember the positions of your favorites so you can revisit them later.



and gold pair at the southern tip of the Swan. Much easier to split are Mizar and Alcor in the handle of the Big Dipper, and Delta (δ) Orionis is another fine pair.

If you find it hard to make out both stars in a double, try clamping or attaching your binocular to a tripod. This will hold it steady for long, leisurely views.

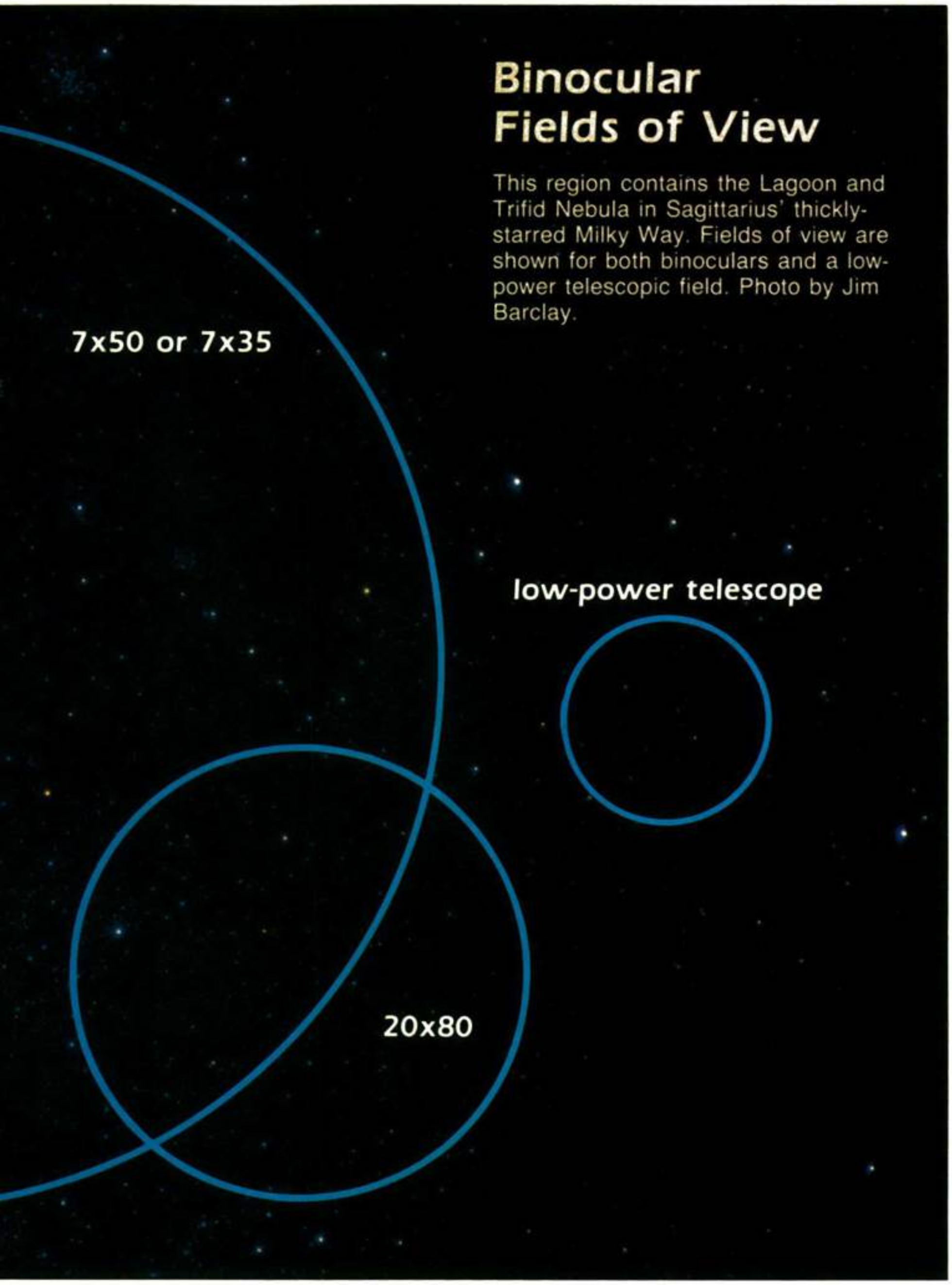
The Sun: Spots and More Spots

When viewing the Sun, it's best to start with a warning: NEVER LOOK AT THE SUN DIRECTLY THROUGH ANY OPTICAL INSTRUMENT. The price of being foolish here is permanent and certainly painful damage to your eyesight — and don't kid yourself that "just a little look" won't hurt. And, no, sunglasses won't provide adequate filtration either. The rule's simple: don't do it.

You *can* observe sunspots safely, however, by using the binoculars to project the Sun's image onto a sheet of white cardboard placed several inches behind the eyepieces. (Rig the binocs on a tripod or you'll go crazy trying to hold them steady and focused at the same time.) An extra plus to this method is that several people can crowd around and look at the sunspots with you — but make sure no one tries to look directly through the binoculars.

Big Binoculars

What about the giant binocs — those monsters you've seen in the glamorous advertisements? Basically, they follow the same laws regarding exit pupils and magnifications as the smaller models do. The main difference lies in their greater light-gathering power and in their often sizable weight. These powerful instruments will enable you to detect stars down to 9th or 10th magnitude, but you



Binocular Fields of View

This region contains the Lagoon and Trifid Nebula in Sagittarius' thickly-starred Milky Way. Fields of view are shown for both binoculars and a low-power telescopic field. Photo by Jim Barclay.

must know how to use them. More than anything else, they need rock-solid support; without it, every object in the field will dance around so skittishly that you'll never get a good look at them.

Perhaps the best way to observe with large binoculars is to mount them directly over an observing chair. Construct a wood framework that fits over your lawn chair and holds the binoculars at eye level. Or simply place a large tripod over the chair so that you can easily move the binoculars around the sky while sitting or lying down. The main thing is to hold them steady with minimal effort on your part.

Discovery is both fickle and relative. You could easily spend all of your observing time looking and never finding. But if you and your binoculars search the sky with the right attitude, you'll see that experiencing new sights and phenomena is easier than you'd expect. I think you'll discover plenty — even if you never do find a comet or a nova.

The greatest advantage to binoculars is that they're light and portable; a drive in the country can turn into a night of discovery if you pack them along. And if you bring a friend, someone unfamiliar with the sky, and show them a variable star or comet — or even just the simple beauty of the Milky Way — then you've given discovery to someone else. And this may be the most important discovery any stargazer can make.

David H. Levy is the comet recorder for the Association of Lunar and Planetary Observers; in November 1984, he co-discovered Comet Levy-Rudenko (1984t). This article is excerpted from Discovery in Amateur Astronomy, *a book he is writing with David J. Eicher.*

A.W. Steinbrecher

Discovering the Sun

WARNING: NEVER OBSERVE THE SUN DIRECTLY THROUGH ANY OPTICAL INSTRUMENT.

If you want to observe the Sun, first mount your binoculars on a sturdy tripod, remembering to cover one of the objective lenses so no one can accidentally look through it. Next, set up a piece of white cardboard several inches behind the other eyepiece so you can project the Sun's image onto the board. Once set up, you'll be able to see sunspots easily — if the Sun's magnetic activity is producing them!

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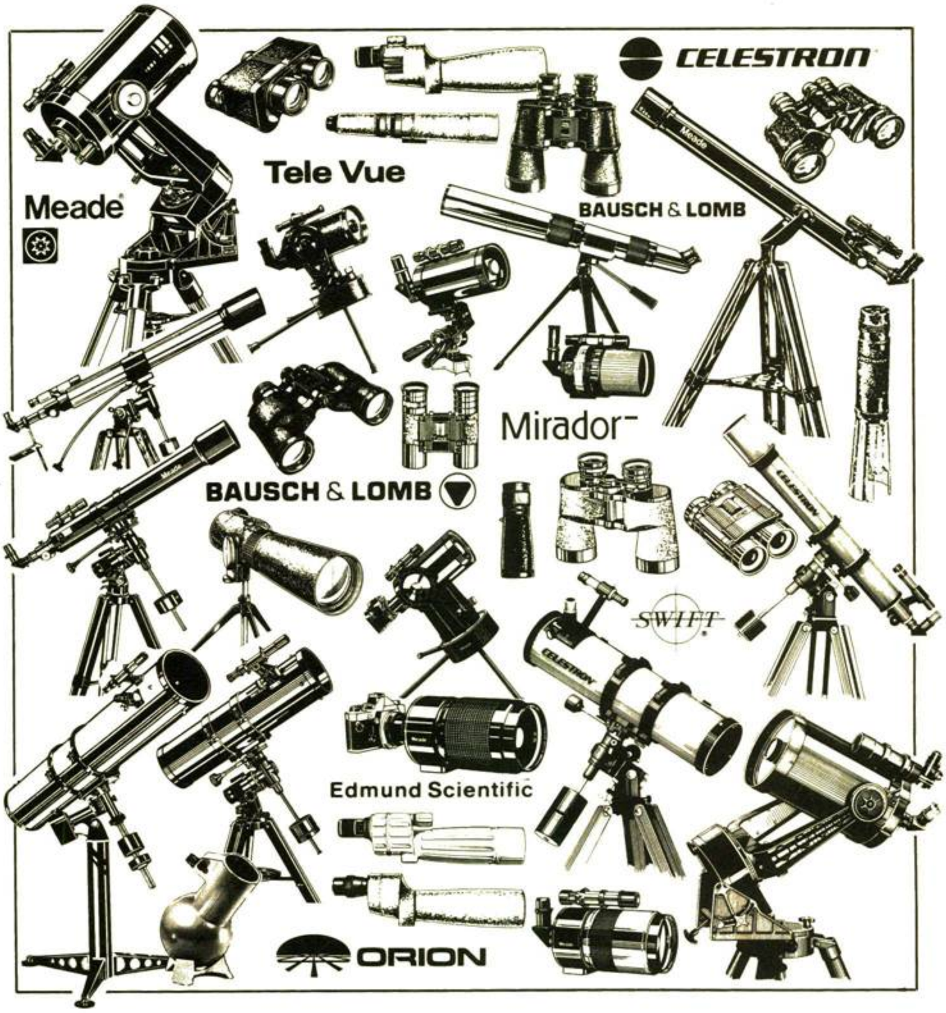

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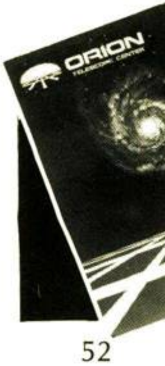

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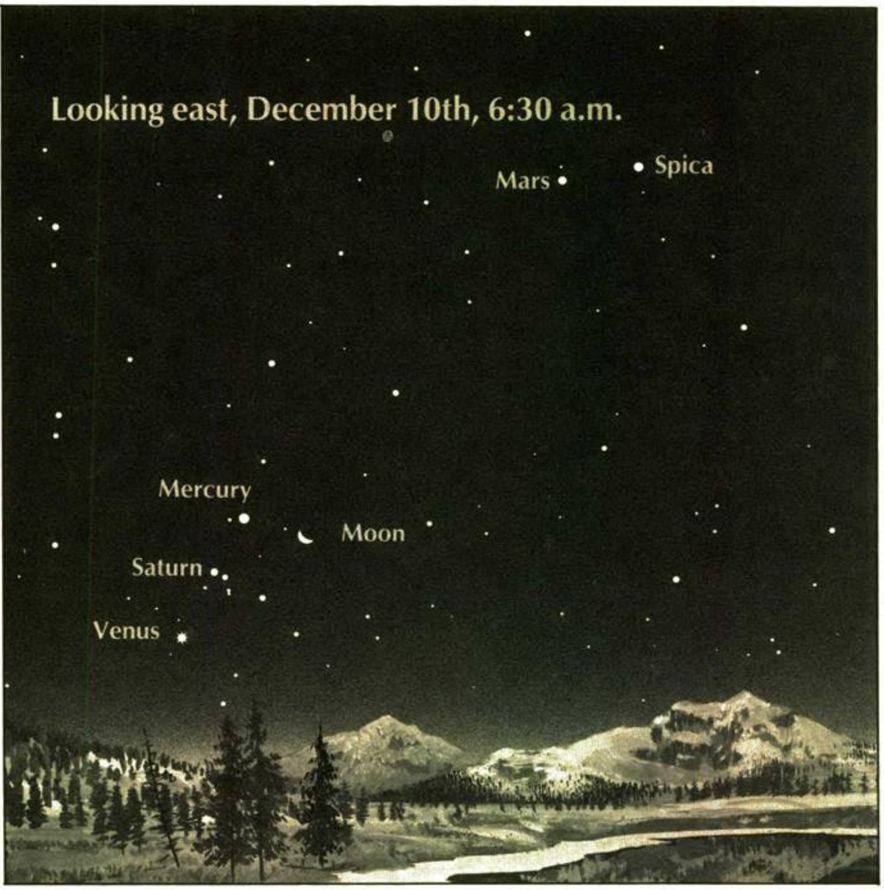
An Occultation of Mars

by
Fred Schaaf



The Wanderers

This is the month you might first catch sight of Halley's Comet with the naked eye — but you'll have to head out into the countryside to do it. Brighter sights are Mars and the Moon, Mercury, and the Geminid meteor shower.

Mars is the second-magnitude reddish planet that rises a few hours after midnight this month. If you get up about 90 minutes before dawn on December's first few mornings, you'll find it about 30° high in the southeast, near the white star Spica in Virgo. Mars lies 3° north of the brighter Spica on the morning of December 2nd.

If you live in the eastern half of North America, you can see a more spectacular sight on the 8th. North of a line running from northeastern Ohio to the coast of central New Jersey, look for a close conjunction of Mars and the Moon, with Mars perched just above the upper edge of the lunar crescent.

If you live south of that line, you'll witness an occultation of Mars by the Moon. The most striking view will be when the planet emerges from behind the unlit part of the lunar disk. This occurs at about 4:02 a.m. for Washington, D.C. and 4:18 a.m. for Miami, Florida. In general, the farther south you are from the Ohio-to-New Jersey line, the later Mars appears. (See map on page 56.)

Far below Mars in the east-southeast during morning twilight, three other planets can be spotted with some difficulty.

The brightest is **Venus**, but it is also the lowest of the three during most of the month and keeps getting lower each day. Venus is 1.6° south of Mercury on December 4th and 1.1° south of Saturn the following day. This unusual grouping rises a little less than one hour before the Sun, however, so the sky will be brightening considerably and viewing may be difficult. By the end of December, Venus rises only about 15 minutes before the Sun and it will be lost in the solar glare.

For information on viewing the Moon, planets, and deep-sky objects with telescopes, see **The Backyard Astronomer**.

Observing conditions for **Mercury** improve rapidly during the first 10 days of December. From about the 10th to the 21st, this zero-magnitude planet rises just before the start of astronomical twilight, about 90 minutes before sunrise. An hour later, with dawn well in progress, Mercury is about 10° above the southeastern horizon. The planet reaches maximum altitude around mid-month and greatest elongation from the Sun (21°) on December 17th.

From December 10th to the 21st, Mercury has several conjunctions. On the morning of the 10th, the slender crescent Moon makes a pretty configuration with Mercury and Saturn. (You may also catch a glimpse of Venus a few degrees below Saturn, if you wait long enough.) During the following week, the separation between Mercury and Saturn decreases and on the 16th, Mercury lies less than a degree north of Saturn. The least impressive of Mercury's conjunctions comes on the 21st, when it shines about 6° north of the first-magnitude star Antares.

As 1985 ends, Mercury rises about 75 minutes before the Sun; **Saturn**, however, comes above the horizon around three hours before sunup. While the sky is still fully dark on December 23rd and 24th, notice that second-magnitude Beta (β) Scorpii lies a little more than a degree from Saturn, but the ringed planet has even closer company. Can you detect the fourth-magnitude double star Nu (ν) Scorpii about 0.2° from Saturn? Few will be able to see it without help from binoculars.

Ten minutes after he started this exposure on August 12th, Brian Skiff of Flagstaff, Arizona, photographed a "shockingly bright" Perseid fireball. He used a 15mm f/2.8 lens and 3M 1000 film.

Jupiter is the lone world visible after sunset, standing out with special prominence at about −2 magnitude in dim Capricornus. On December 15th, the Moon will pass fairly close to the planet, a prelude to next month when **Halley's Comet** joins them to form an interesting ensemble.

December is the month when Halley's Comet may finally be bright enough for naked-eye observing — but at press time Halley is dimmer than first predictions indicated. See the chart in Gazer's Gazette, beginning on page 30, which show where to look for the comet on nights when the Moon is not interfering.

Another phenomenon that benefits greatly from a dark sky is the **Geminid**

December's Night Sky

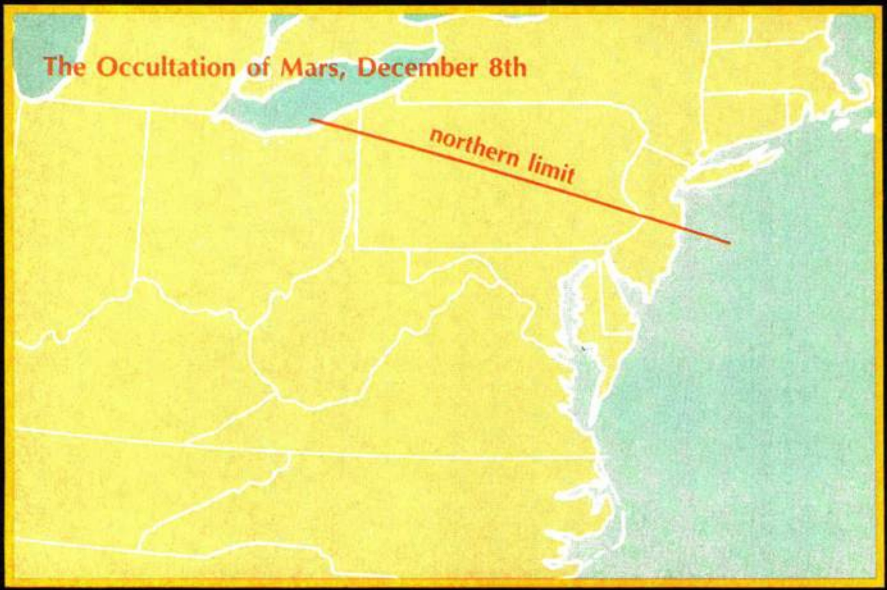
Last Quarter
December 5
4:01 a.m. EST

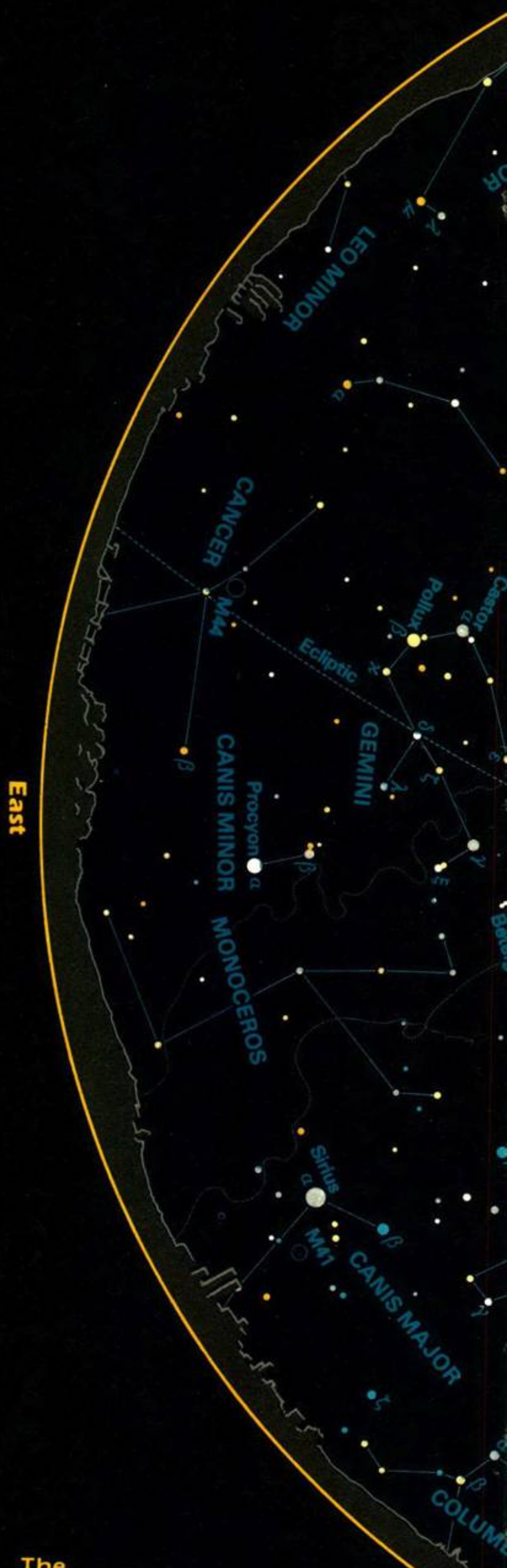
New Moon
December 11
7:54 p.m. EST

First Quarter
December 18
8:58 p.m. EST

Full Moon
December 27
2:30 a.m. EST

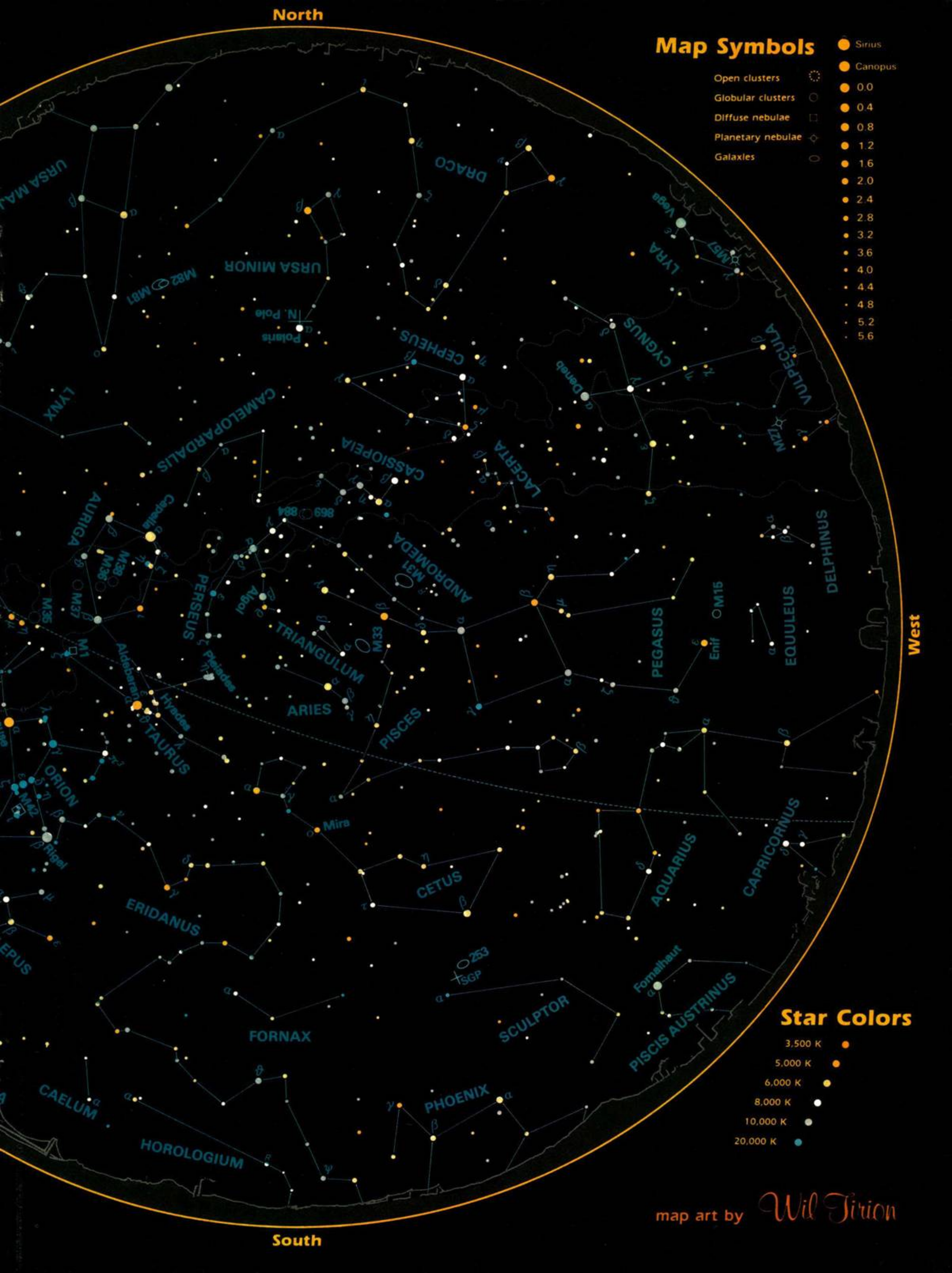
4th	In the hour before Sunrise this morning, look for Venus and Mercury close together in the eastern sky.
5th	Last Quarter Moon occurs at 4:01 a.m. EST.
6th	From today through the 31st, Mercury will be at least 5° high in the eastern sky, 45 minutes before sunrise, providing good opportunities for spotting it.
8th	The Moon passes near Mars, occulting it for viewers on parts of the East Coast (see text).
10th	The Moon is closest to Earth at 7:43 p.m. EST: 228,875 miles. Also, Uranus is in conjunction with the Sun.
11th	New Moon occurs at 7:54 p.m. EST.
12th	The Geminid meteor shower reaches peak activity tonight and early tomorrow morning; from a dark-sky site, you should see 50 to 60 meteors an hour at best.
16th	Mercury passes half a degree north of Saturn in the predawn sky today; look for it low in the east-southeast during the hour before sunrise.
17th	Mercury is at greatest western elongation from the Sun.
18th	First Quarter Moon occurs at 8:58 p.m. EST.
21st	Winter begins as the Sun reaches its farthest point south on the celestial sphere at 5:08 p.m. EST.
23rd	The Moon is farthest from Earth at 2:16 a.m. EST: 252,029 miles.
25th	Neptune is in conjunction with the Sun.
27th	Full Moon occurs at 2:30 a.m. EST.


The Occultation of Mars, December 8th
northern limit


East
LEO MINOR
CANCER
M44
Ecliptic
Pollux
Castor
GEMINI
CANIS MINOR
Procyon
MONOCEROS
Sirius
M41
CANIS MAJOR
COLUM

The Star Dome shows how the sky looks at:

9:30 p.m. on December 1st
8:30 p.m. on December 15th
7:30 p.m. on December 31st


North
South
West
Map Symbols
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies
Sirius
Canopus
0.0
0.4
0.8
1.2
1.6
2.0
2.4
2.8
3.2
3.6
4.0
4.4
4.8
5.2
5.6
URSA MAJOR
DRACO
URSA MINOR
M82
M81
N. Pole
Polaris
LYRA
Vega
M57
CEPHEUS
CYGNUS
Deneb
VULPECULA
M27
LYNX
CAMELOPARDALIS
CASSIOPEIA
LACERTA
AURIGA
Capella
869
884
ANDROMEDA
M31
DELPHINUS
M38
M36
M37
PERSEUS
Algol
M33
TRIANGULUM
M15
PEGASUS
Enif
EQUULEUS
M1
Aldebaran
Pleiades
Hyades
TAURUS
ARIES
PISCES
ORION
M42
Rigel
Mira
CETUS
AQUARIUS
CAPRICORNUS
ERIDANUS
LEPUS
253
SGP
Fomalhaut
FORNAX
SCULPTOR
PISCIS AUSTRINUS
CAELUM
PHOENIX
HOROLOGIUM
Star Colors
3,500 K
5,000 K
6,000 K
8,000 K
10,000 K
20,000 K

map art by Wil Tirion

Top left: Polar star trails and a meteor. Mark Coco caught this fireball on June 15th at Table Mountain Observatory in California. He used a 28mm lens and a 1-hour exposure at f/2.8 on Ektachrome 400 film. Below left: On June 14th, John Olson of Knoxville, Tennessee, photographed the Moon and Venus with a 50mm lens and VR 400 film.

meteor shower. The average Geminid is about second magnitude; if you want to see as many as 50 or 60 per hour at peak, get away from city lights. The night of maximum this year should be December 12th to 13th. The Moon sets right after the Sun that evening, leaving the sky dark for these moderately-fast meteors which appear to radiate from near the star Castor. The radiant and the probable meteor rates are highest around 2 a.m., but Gemini is well up in the east by 10 p.m. so you may wish to begin your counts then or even earlier. If you think you're going to be clouded out on the big night, the preceding and following nights also offer good Geminid displays.

The Starry Sky

A familiar pattern in the winter sky is three bright stars very close together in a line. These stars belong to **Orion** the Hunter and form his belt. Many backyard astronomers know the names of these second-magnitude stars but don't remember which name applies to which star; from east to west they are Alnitak, Alnilam, and Mintaka. Go out early on a December evening and you'll see these stars rising as a nearly vertical line in the eastern sky. The belt of Orion straddles the celestial equator, midway between Polaris and the south celestial pole.

These stars, however, aren't the constellation's brightest: blue Rigel and orange Betelgeuse are both first-magnitude stars. Rigel, meaning "knee," marks the Hunter's western knee. Like most stars in Orion, it is a blue giant — a very large, hot, and extremely luminous star.

Betelgeuse, a *red* giant star, is normally not as bright as Rigel, but is perhaps even more interesting. Somewhat variable in brightness like all red giants, it is much cooler and immensely larger than most other stars. Even for a red giant, Betelgeuse is big; if it was put in our Sun's place, it would fill the solar system out to twice the orbit of Mars. See if you can note any variation in the brightness of Betelgeuse.

Orion has a sword hanging from his belt. The weapon appears as a nearly north-south line of fairly dim stars and is an interesting pattern to the naked eye, but only binoculars or a telescope will clearly show the special "gleam" in that sword. The gleam is M-42, the Great Orion Nebula, a softly-glowing cloud hidden from the naked eye by the glare from the star Theta (θ) Orionis. Perhaps no object is more beautiful in telescopes.

Although Orion is the central figure of the winter constellations, ranged all around him are five other constellations with first-magnitude stars.

Northwest of the Hunter is Aldebaran (magnitude 0.9), the eye of **Taurus** the Bull. The striking V of stars with Aldebaran in the center is the large Hyades star cluster. The smaller but even more beautiful dipper-shaped asterism farther west is the Pleiades star cluster.

To the north of Orion is the bright star Capella. Yellowish Capella is similar in brightness to Rigel but is even more similar to summer's Vega and spring's Arcturus. Capella is in the constellation of **Auriga** the Charioteer. Auriga forms a pentagon shaped like the outline of a little house.

Northeast of Orion is **Gemini** the Twins. Castor, the second brightest star in Gemini, shines at magnitude 1.6. The brightest star in Gemini is Pollux, which gleams about half a magnitude brighter than Castor. These stars mark the heads of the twin brothers and are easy to compare because they lie only 4½° apart.

East and southwest of Orion, respectively, are Procyon and Sirius. Procyon, part of the Little Dog, **Canis Minor**, is almost as bright as Rigel, but at magnitude −1.42, Sirius is overwhelmingly brighter. Its constellation of **Canis Major** the Large Dog is also bright and prominent, but it tends to be overlooked because it is so close to the blazing Sirius.

Skylore

The constellation of Eridanus the River is not very prominent to most of the world's stargazers. If you live north of about 30° north latitude, you can see no star in it brighter than third magnitude. One such star is β Eridani, a star near Rigel. Also, the splendor of Orion further distracts the viewer away from Eridanus.

Despite these shortcomings, Eridanus extends a long way across the sky and its lore dates far back into classical antiquity. The first mention of Eridanus appears in the writings of Hesiod, a Greek who lived in the 8th century B.C. Although Leo is Latin for "lion" and Taurus is Latin for "bull" (both derived from essentially the same words in Greek), Eridanus does not mean "river" in Greek or Latin. It is simply the *name* of a river. The question is, which one?

In Hesiod, Eridanus seems to refer to an ancient river called the Phasis. In his 1899 book *Star Names*, celestial lore expert R.H. Allen wrote that this is the modern Rioni, which the Turks call the Fasch. A look at a contemporary atlas shows the Rioniy as a small river now within the borders of the Soviet Union. It flows into the Black Sea, which was called the Euxine Sea by the ancient Greeks. It is supposed to be the one that emptied into the Black Sea near where Jason obtained the Golden Fleece.

Late classical Greek writers called Eridanus the heavenly extension of the little brook which flowed from their Acropolis. The Romans, naturally, identified the constellation with Italy's largest river, the Po.

But many ancient writers linked Eridanus in the sky to purely legendary rivers on Earth. Sometimes it was Oceanus, the River of Ocean, believed to flow clockwise around all the lands of Earth. Eridanus was also a legendary stream rumored to flow into the sea from northwestern Europe. Other identifications of this kind continued to be made into the Middle Ages and beyond: Eridanus was said to be the river Gihon mentioned in Genesis ii, 13. It was also called the River Jordan and even the Red Sea which parted for Moses during the exodus from Egypt.

What other real rivers, famous in ancient and medieval times, have been pictured in these stars?

The Euphrates, of course. Together with its famous mate, the Tigris, these rivers bound the region called Mesopotamia — literally, "between the rivers." This region forms much of the famed Fertile Crescent, birthplace of early civilizations.

Only one river of ancient times was as widely known as the Tigris and Euphrates — the Nile. It, too, was related to starry Eridanus and in one special way it is very appropriate: both are unusual in that they flow great distances from the south to the north! To the ancients, any river that lay on the margins of the known world could develop a legendary status and be related to Eridanus. Thus we also have the Ebro, which Greek navigators found in Spain, and the Rhine and Rhone — all of which have been linked to Eridanus.

What made this rather faint constellation so interesting to the ancients? To begin with, they had clearer and darker skies than we do today, and they would have noticed that the stars in this part of the heavens seem to form a meandering pattern. This pattern does suggest a river (or a snake) and rivers have always been important to civilization.

The size of Eridanus was also impressive, and it has gotten larger and more impressive in modern times. The ancients regarded the star θ Eridani, now at 40° south declination, as the end of the river. Indeed, its present name is Acamar, a variant form of Achernar, which comes from the Arabic phrase meaning "end of the river."

In modern times, the north-south extent has increased from about 40° to almost 60°. The new end of the river is now a far southern (declination −57°) first-magnitude star known today as Achernar. Viewers in the southernmost United States (below 30° north) can glimpse Achernar at about 9 p.m. in early December when it culminates just above their due south horizon.

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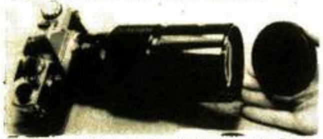

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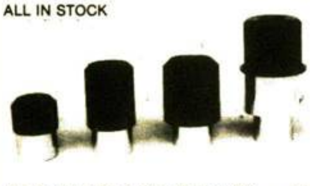

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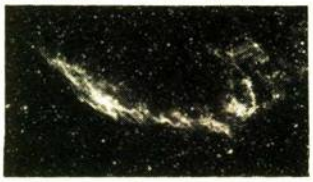

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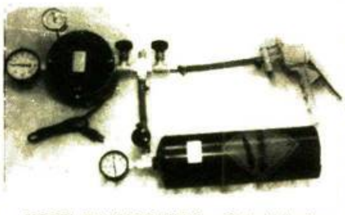

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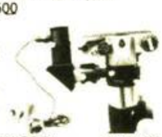

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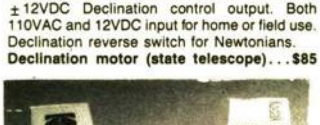

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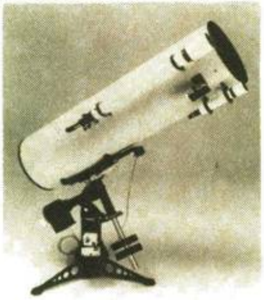

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The DS Series of 10" and 16" reflecting telescopes are ideal for deep-sky viewing and photography.

DS-10A, 10" f/4.5 with motor drive ($150 list)	$995

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ASTRONOMY
Reviews

NightStar: the flexible star map
flexible "planisphere," $44
The NightStar Company (1985)
[publisher's address: 1334 Brommer Ave., Santa Cruz, CA 95062]

"It looks," she said, "like a giant diaphragm."

I had to agree.

But NightStar *is* a real breakthrough in teaching astronomy to beginners. Touted as an "innovative flexible three-dimensional star map," NightStar is truly capable of showing the sky from any time and place on Earth. And I agree with Guy Ottewell's assessment, quoted in the NightStar Company's sales literature, that NightStar is "a thing of genius."

Picture it as a medium-size dark blue salad bowl with white star dots, brownish constellation lines, and pale blue names printed all over it, inside and out. It's eight inches across and about four inches deep. It feels for all the world like a greasy inner tube — very, very tactile and a bit "icky," too. It gives off a hard-to-forget smell. But it's the neatest star map I've ever seen.

Most star maps are, of necessity, as flat as the paper they're printed on. Celestial globes are fine for three-dimensionality, but they usually represent the sky as you would see it from the outside looking in — so they're hard to use as maps because the star patterns appear reversed.

NightStar changes all that.

Imagine, if you will, an eight-inch diameter celestial globe covered with stars. Now imagine that instead of being hard, the globe is soft. Try to picture what would happen if you gently crushed one side of this soft globe until it folded into the other side, inside out. You'd then have a soft bowl full of stars, right?

Now imagine putting a rigid ring inside the bowl at its rim, pumping out any remaining air between the inverted half of the globe and the ordinary convex side, and finally injecting a silicone lubricating oil between them. Got that? Here's the clever part: if you push on the surface of this "bowl," the skin will slither around, flowing over the rim, the inside going to the outside and the outside to the inside.

And — here's the bit that's "pure genius" — you can make the stars on the inside bowl surface appear to rise, move across it, and set — just as the real stars move across the inverted "bowl" of the real sky. The idea is that you then hold this thing over your head and look into it.

Inventor Bruce King, a New Zealander who conceived NightStar 13 years ago in England, now manufactures it. "When I first patented the idea," the sales literature quotes him as saying, "no one thought it could be made." I believe that. I spent a lot of time trying to figure out how King ultimately solved the manufacturing problem. NightStar is cast from a very smooth, soft plastic. I'd guess the molding nipples double as the north and south celestial poles, and it looks to me as if the lubricant is squirted through the northern one since the plastic appears a bit melted there. But maybe it's made in halves and sealed somehow at the equator. In any event, King now resides in California and makes NightStars in a shop in his garage.

NightStar is useful anywhere on Earth because it's as easy to change the angle between the pole and horizon (the stiffened rim of the bowl) as it is to make the stars rise and set. The NightStar is light enough to take on camping trips. It's a good conversation piece.

NightStar comes in a big cardboard box, and includes a clearly-written manual and plastic gadgets that attach to the poles so you can set the latitude angle and time accurately if you feel inclined to. I enjoyed setting the latitude by eye, then coaxing the stars to rise oozily in the east, slither across the meridian, and fold over the western side of the bowl. NightStar also comes with two plastic planet strips that fit the ecliptic. One strip shows the planets for 1985 and the other shows them for 1986. I didn't try them, but they looked like they'd work.

At $44, NightStar seems a bit pricey, but it's one of those things an astronomer seems to want instinctively. You might, however, be able to justify spending that much money to yourself because NightStar represents the vault of the night sky more accurately than any flat chart can. It would make an unusual gift. Or perhaps you could put it to use teaching kids the stars. However, I think the best reason for getting a NightStar is that it's so conceptually elegant. If you're fascinated with astronomy, you owe it to yourself to buy a NightStar. *Richard Berry.*

Astronomy
Storm Dunlop
192 pages, paperback, $8.95
Macmillan (1985)

Pocket-size field guides to astronomy abound nowadays; this is Macmillan's entry, subtitled "A Step-by-Step Guide to the Night Sky." The author is a Fellow of the Royal Astronomical Society and an active amateur astronomer in the U.K.

The first half of the book is called "Beginning Astronomy" and covers the basics of learning your way around the sky. It discusses eyesight, twilight, and seeing, then goes on to explain about naked-eye observing, using binoculars and telescopes, and astrophotography. No one topic is treated with much depth, but there's enough presented to get beginners squared away on the fundamentals.

For learning the constellations, the book presents north and south polar charts (stars to fifth magnitude) and six covering the middle ranges of declination. The charts have the chief constellation stars connected by red lines, while grey arrows serve as pointers to stars in different constellations. The same maps appear later in the book, but this time in full regalia: right ascension and declination are labeled, and the official constellation boundaries replace the lines connecting the star patterns. One drawback is the lack of a series of "sky domes" which show the sky at 10 p.m., say, throughout the year. I suspect complete beginners will have some trouble going from the star charts to the sky they'll see on any given evening.

Part two, "Exploring the Sky," deals with astronomy-as-a-science. In it, you find short discussions of celestial objects in terms of what they really are and what they look like to the observer. The zodiacal light, aurorae, and meteors are followed by the Moon, the Sun, the planets, and comets. Stars — variable, double, and clustered — are each treated briefly, followed by nebulae and galaxies. Lastly, there's an appendix listing other books, periodicals, and organizations for further information and an index that caps the lot.

The coverage in the observing section is strongly weighted in favor of solar system objects (by about a 3 to 1 ratio), which seems sensible in a book aimed at neophyte observers. It's easy to be thrilled by the Moon and planets, whereas an interest in galaxies and other faint deep-sky objects tends to come later.

I have, in the end, two criticisms. First, I wish the book included date references to certain specific events, such as eclipses. If you choose not to give a list of upcoming eclipses and where they're visible, all right, but at least tell your readers where to look for the current year's events. (The book does, however, provide a list of opposition dates of the superior planets — elongations and conjunctions for Mercury and Venus — for the years 1985 to 2000.)

My other criticism concerns the section on variable stars. Here the reader is taken step-by-step through the process of estimating a variable star's brightness; 12 variables are tabulated and there's even a chart for AC Herculis. But after mobilizing all this effort, nowhere is the reader told what to do with the brightness estimates — and this after several pages have been spent on the importance of keeping an observing log! Dunlop should have specifically directed the reader to get in contact with the AAVSO or the Variable Star Section of the British Astronomical Association, both of whose addresses are provided in the appendix.

Apart from these matters — which are less important than the space taken to point them out implies — I'd say this field guide is a pretty good introduction to observing. I wouldn't recommend it as a beginner's one-and-only, but it certainly gathers a lot of basic material very compactly. *Robert Burnham.*

Arthur Storer . . . Forgotten Man of Science

Lou Rose and Michael Marti
185 pages, hardcover, no price given
Calvert County Historical Society (1985)
[Publisher's address: P.O. Box 358, Prince Frederick, MD 20678]

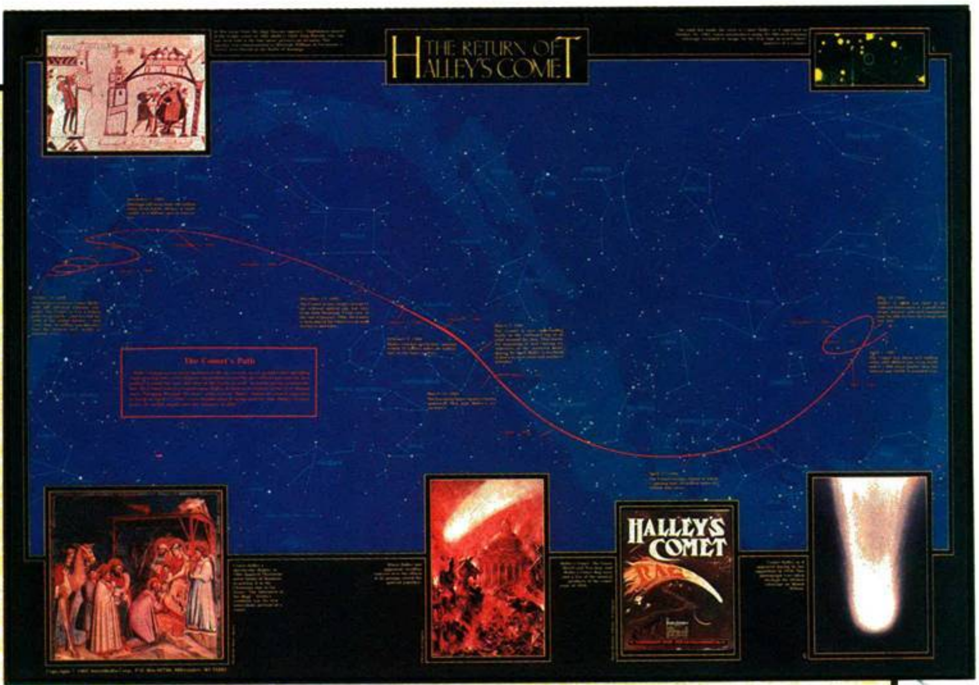
The full title of this book runs: *Arthur Storer of Lincolnshire, England, and Calvert County, Maryland: Newton's Friend, Star Gazer, and Forgotten Man of Science in Seventeenth-Century Maryland.* Born in the same village as Isaac Newton, Arthur Storer was a year or two younger; he and Newton were friends from childhood. Much later, after emigrating to Maryland, Storer followed the comets of 1680 and 1682 (the latter being Halley's) and was the only North American "natural philosopher" whose work Newton cited by name in his great *Principia*. The authors of this biography attribute Storer's near-total obscurity at present — even his grave is lost — to the fact that: (a) he died young, (b) he never married, and (c) he left no offspring, "legitimate or otherwise."

Sky Travel — A Window to Our Galaxy

Commodore Educational Software
5¼" floppy diskette and manual
No price given

For owners of Commodore 64 and Commodore 128 home computers, *Sky Travel* is a planetarium-on-a-disk. Loading the program takes approximately three minutes. The opening scene is a representation of the night sky as it would appear to an observer in Washington, D.C. at 4:15 a.m. on January 1st, 1985.

The program outlines the major constellations, displays a crosshair cursor, and indicates the direction of the north



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celestial pole. At the right of the sky map is a vertical orange bar, the "data window," which shows date, time, time zone; elevation, azimuth, right ascension, and declination of the cursor; rate (of time passage); viewing angle (9° to 72°); and a function key menu. Across the bottom of the screen, a "text line" keeps you abreast of the compass direction which you are facing.

Stars are represented by enlarged tokens whose size and pixel patterns correspond to their brightness. Deep-sky objects are displayed using various pixel patterns to represent open clusters, globular clusters, elliptical and spiral galaxies, planetary nebulae, and diffuse nebulae. Planets are shown by symbols or proportionally-sized tokens depending on the setting.

The real power of *Sky Travel* lies in its ability to provide information when you're about to embark on an observing session. To begin, using the SET mode, you set the display for any day, date, and time from 9999 B.C. to 9999 A.D. In SET mode, the data window informs you of the date, time, Julian day, and calendar setting. You can enter dates using the Julian or Gregorian calendar systems; in its default mode, the computer converts all input dates into Julian days before beginning computations.

To set the display for your own location, you must enter the MAP mode in which a Mercator projection of the Earth's surface replaces the sky display. Tables in the appendices list the latitude and longitude for major cities in the continental U.S., as well as many outside the country. To set latitude and longitude, all you must do is change the data window display to the appropriate numbers, or you can "drive" the cursor via joystick or keyboard over to the appropriate map location.

After setting your location in MAP mode, you return to SKY mode to display your sky on the day and time specified while in SET mode. You may then observe in any direction you like, using the joystick or keyboard to slew your window on the sky. When you note an object of interest, simply place the cursor over the object, press F7 (or the joystick "fire" button) and after a bit of disk activity a description of the object will appear on the text line.

This function is called INFORM; the information contained in it varies with the objects. For a star, you get the Henry Draper catalog number, its designation (i.e. Alpha Carinae), spectral type, and other bits of useful information. For a planet, you get details of its orbit and surface conditions. For a deep-sky object, the Messier and NGC numbers, type of object, and popular name (if any) are included.

The program has many options. The FIND command, for instance, will locate and place under the cursor any of the planets, the Sun, the Moon, or any one of the 88 constellations at the particular time and location for which the program is set. CHART mode displays a representation of the sky with right ascension and declination lines added, and with black stars on a white background. Options useful with the CHART and SKY modes are: Lines (toggles the constellation lines off and on), Names (ditto the constellation names), Deep Sky (ditto the deep sky tokens), and Track (keeps objects located under the cursor via FIND).

Finally, you can use your Commodore printer to make a copy of any of the displays — handy for preparing charts for a night's observing. (I liked it for generating radiant maps for meteor observing.)

Sky Travel uses epoch 2000.0 star coordinates and keeps track of precession in all computations which involve epoch changes. (Stellar proper motions are not included in the computations, however.) Commodore claims accuracy to 1 minute of arc over the span 9999 B.C. to 9999 A.D. In computations of planetary positions, *Sky Travel* takes into account perturbation effects as well as orbital decelerations of Earth and Moon due to tidal forces.

One omission detracts from the overall excellence of the program. A function for computing and listing events such as occultations, transits, and eclipses, and for displaying future dates of these events would have been useful. But the program

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does display these events when you reach a day on which they are scheduled to occur — right down to darkening the sky during a total solar eclipse!

Sky Travel includes over 1200 stars, 88 constellations, 8 planets, and the 1985/86 positions of Halley's Comet (which appear on the display when its predicted magnitude brightens into the naked-eye visible range). The manual is complete, simple to follow, and includes sections on basic astronomy, constellations, future events, conversions, and an extensive list of supplemental reading in astronomy.

All in all, *Sky Travel* is a great new astronomy package, easy to use, and versatile. Most computations require only a few seconds; a few of the more complex calculations take longer due to precession computations, etc. This program is well suited to both the budding backyard astronomer and the seasoned observer. *Mark Tosiello.*

The Jodrell Bank Telescopes
Bernard Lovell
292 pages, hardcover, $19.95
Oxford University Press (1985)

This work describes the planning and construction of several large radio telescopes at Jodrell Bank, England, from the late 1950s to the present. It encompasses everything from tiny, experimental designs to the modern, multi-dish array called MERLIN.

Stellar Radial Velocities
A.G. Davis Philip and
David W. Latham, eds.
455 pages, softcover, $30
L. Davis Press (1985)

Radial velocities of single stars, binaries, variables, and clusters are discussed in these proceedings from the International Astronomical Union's colloquium #88.

William Whiston: Honest Newtonian
James E. Force
208 pages, hardcover, $37.50
Cambridge University Press (1985)

This is a biography of Isaac Newton's controversial successor who, as Lucasian Professor of mathematics at Cambridge in 1703, mixed religion and physics together in his teachings.

The Universe for Children
David H. Levy
115 pages, softcover, $9.95
Everything in the Universe (1985)

This manual explains "how astronomy-minded adults can help children to love the sky" and explores teaching astronomy to kids — from their first look through a telescope to starting an astronomy club.

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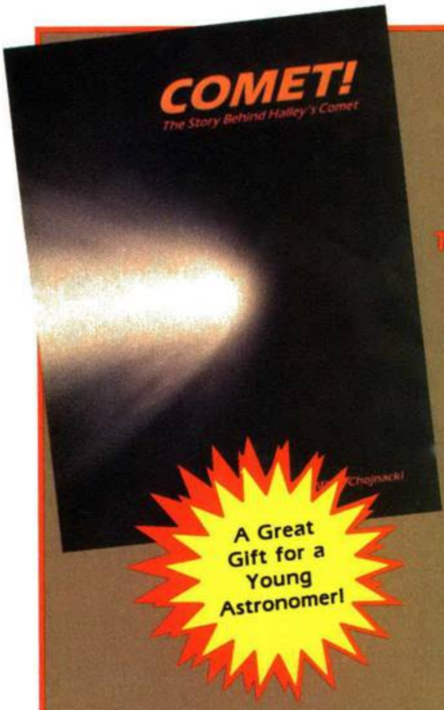
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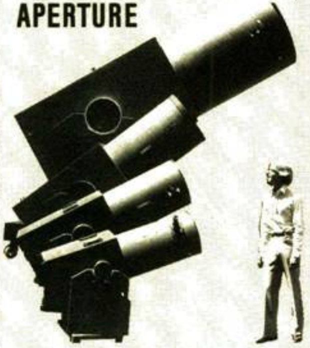

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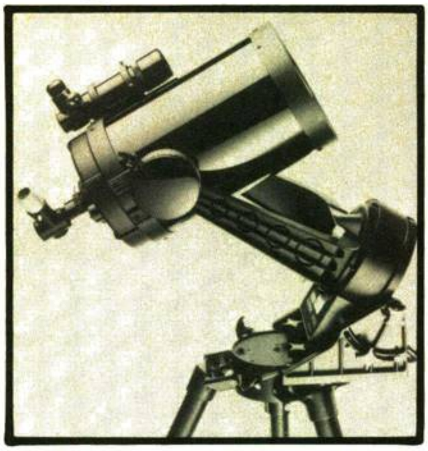

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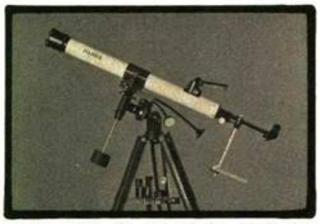

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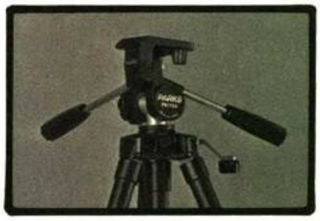

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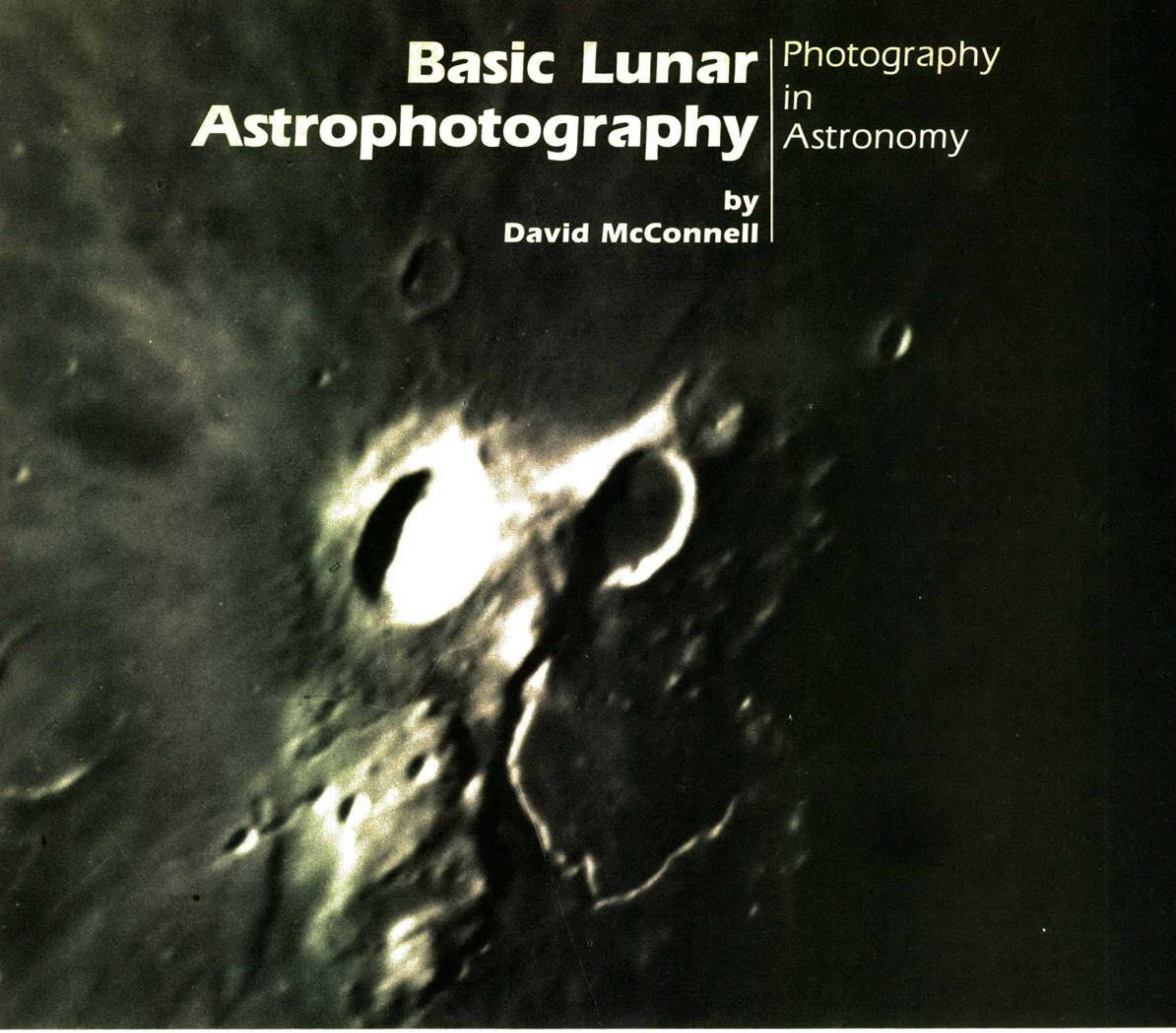
Basic Lunar Astrophotography

Photography in Astronomy

by
David McConnell



Schroeter's Valley is an intriguing sinuous rille that winds north and west from the bright crater Aristarchus in Oceanus Procellarum. Photo by Jean Dragesco with a 14-inch Schmidt-Cassegrain telescope.

If you own a camera and a telescope, you've probably had a go at photographing the Moon. But unless you were a lot more skilled than most, the results probably looked sort of, well, amateurish.

Photographing the Moon *seems* like the easiest form of astrophotography — surely anyone with basic astronomical and photographic equipment can do it! Yet while this is true in large measure, many a lunar photo has slipped down the crack between what seems easy and what is.

Getting Ready

To basics then: any good-quality astronomical telescope is suitable, even the humble 60mm refractor. Catadioptrics, such as Schmidt-Cassegrains and Maksutovs, work very well. Newtonian reflectors are also fine, though some may not allow the camera body to reach down to the focus — in which case the main mirror must be moved forward. (For fix-it tips, see "Building a 6-inch Reflector, part 3," ASTRONOMY, August 1977.) The telescope can be on an alt-azimuth mounting, but these are awkward. You'll get better results with an equatorial mount and clock drive.

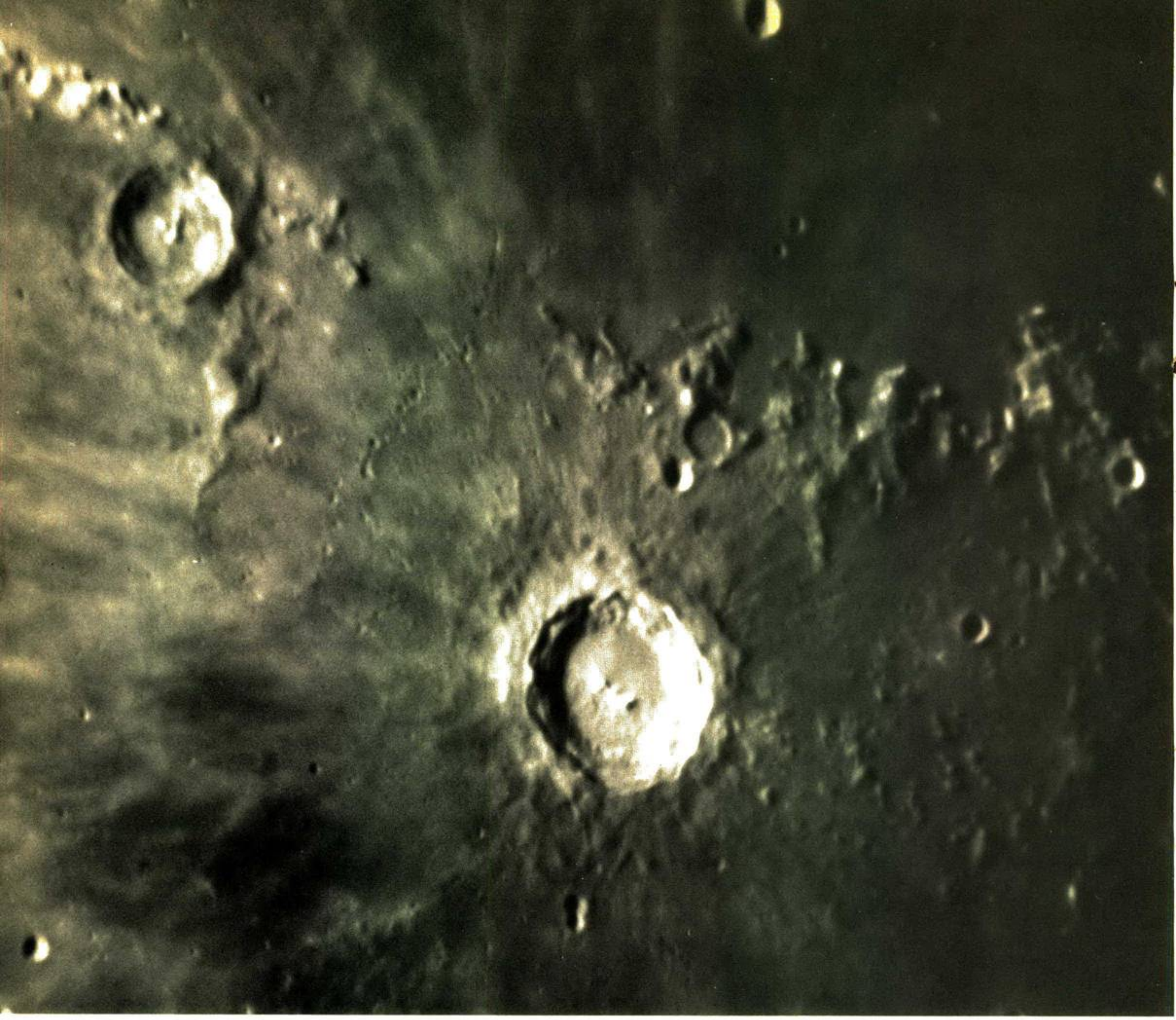
The best camera to use, fortunately, is the most popular kind today, the 35mm SLR. Only the camera body is attached to the telescope, which effectively becomes the camera lens. If your camera allows it, you should replace the standard ground-glass focusing screen with a clear focusing screen. (This helps in focusing at dim f/ratios.) Some of the more expensive SLRs also let you replace the standard prism viewfinder with a special magnifying viewfinder, but this is not essential.

Lastly, you will also need an adapter which couples the SLR body to the eyepiece focuser sleeve. The adapter should be designed to enclose an eyepiece (for eyepiece projection) and be painted flat black inside. These adapters are commonly available through telescope accessory dealers — see the ads in the magazine.

When you have the camera attached to the scope, check its balance. Move the tube around in its saddle as needed and readjust the counterweights. Try to trim the balance so that the scope sits easily in place when the r.a. and dec. clamps are loose, no matter where the telescope's pointing.

What's My Focal Length?

The secret of fine lunar photography is



good seeing and ample focal length. We'll cover seeing a little later, but focal length and its relative, focal ratio, need some discussion. High magnifications come from long focal lengths which produce correspondingly slow focal ratios. It's not impossible to have focal ratios run as high as f/150. It's essential to know the actual focal ratio because it determines the all-important exposure time, just as in conventional photography.

When you attach the camera to the telescope focuser without using an eyepiece in the adapter, the system's focal ratio is the same as the telescope's. So far, so good. However, using the adapter in conjunction with an eyepiece — to get increased magnification by projection — complicates matters. The final or effective focal length (e.f.l.) and the effective focal ratio (e.f.r.) of the system depend on a "projection factor" calculated from two numbers: the focal length of the eyepiece and the projection distance from the eyepiece to the film.

Compute the projection factor as follows:

factor = (D/E) − 1

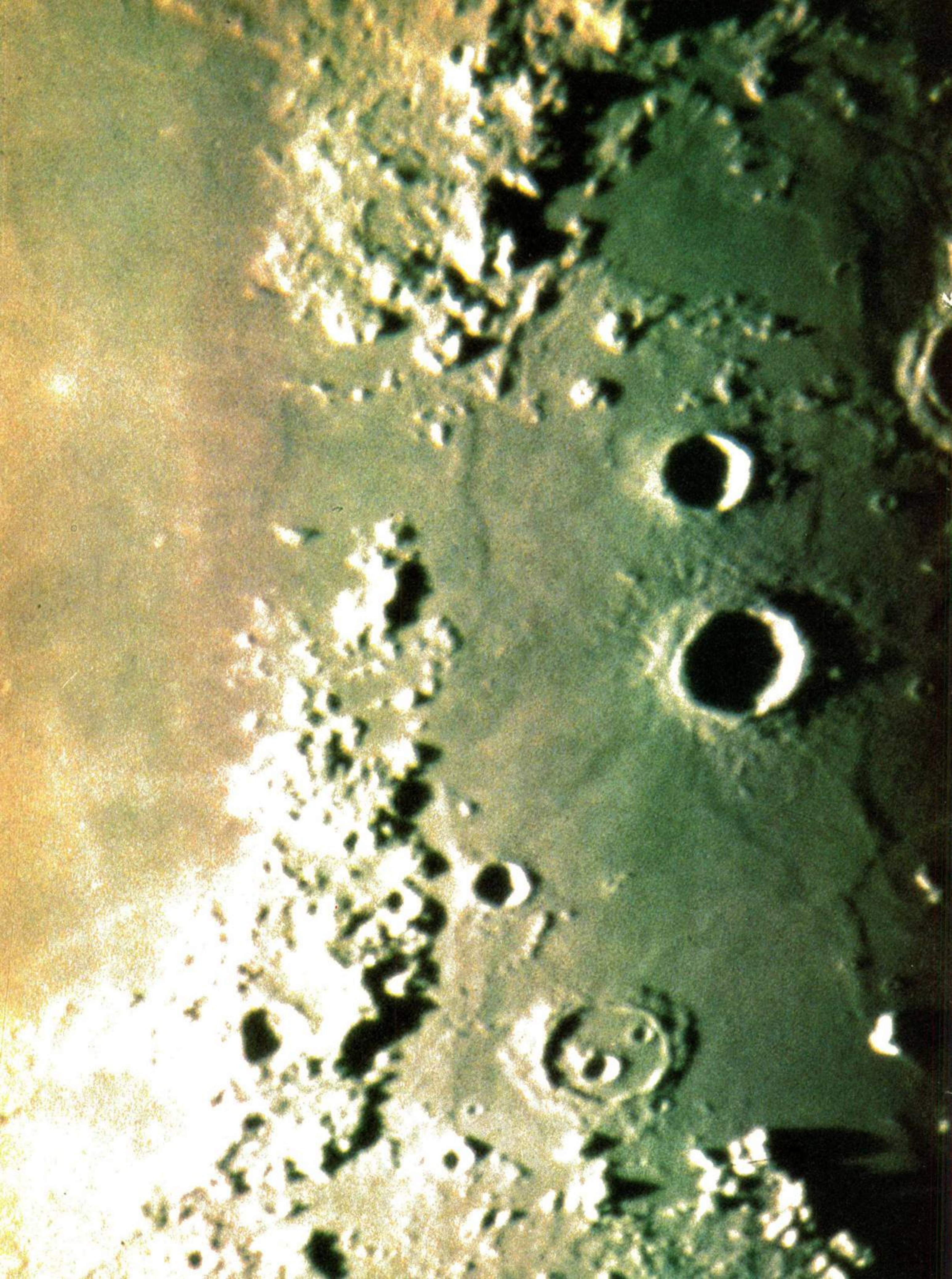
where D is the distance (in millimeters or inches) from the center of the eyepiece's optics to the focal plane of the camera, and E is the focal length of the eyepiece (in the same units).

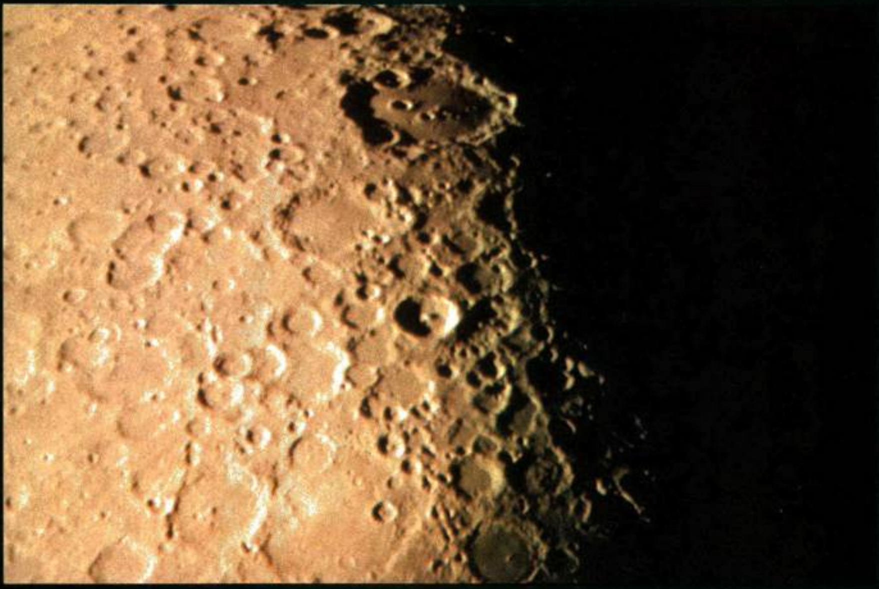
The effective focal ratio and focal length are given by multiplying the factor times the original focal ratio and focal length. For example, let's take a 60mm refractor with a 600mm focal length. As is, you have an f/10 system. Using a 25mm eyepiece and your adapter, you find that the distance from the eyepiece to the film plane is 100mm. Working through the arithmetic, you get: (100/25) − 1 = 3. For the 60mm refractor, then, the e.f.l. is 3 x 600mm = 1800mm, and the e.f.r. is 3 x f/10 = f/30.

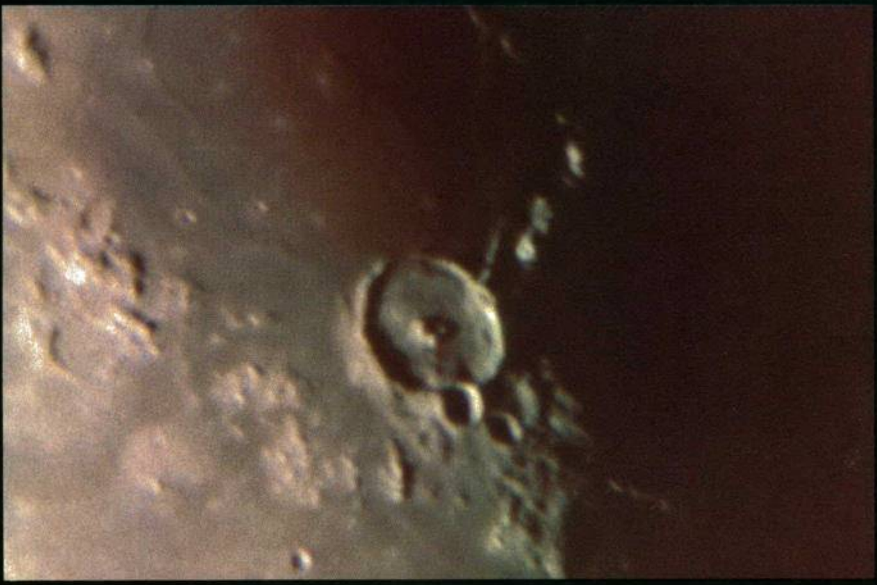
Right: Greg Terrance photographed the almost-Full Moon with an 8-inch SCT and a 1/60-second exposure at f/10 (prime focus). Above: The early morning Sun rises over Copernicus and Eratosthenes, taken by Brian Tkachyk with an 8-inch SCT and a 2-second exposure at f/50 on Technical Pan film.

Or take a 6-inch f/8 reflector with a 12mm eyepiece and a 6-inch projection distance. Six inches is 152mm, so (152/12) − 1 gives a factor of 11.6. Applying the factor, we get 11.6 x 48 inches = 557 inches (about 14,150mm) for the focal length and 11.6 x f/8 = f/93 as the final f/ratio.

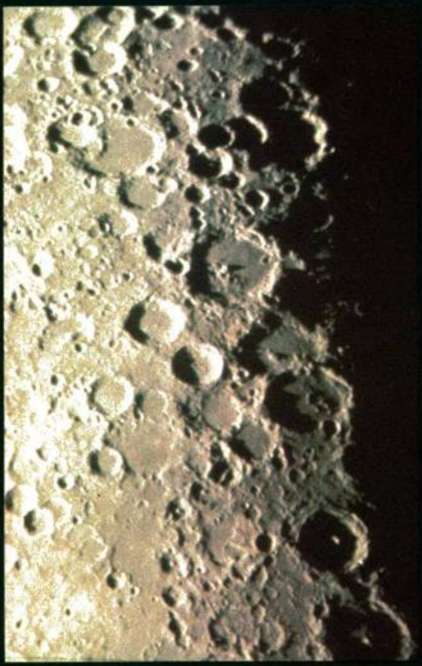
Barlow lenses, which have negative focal lengths, alter the equation slightly:







Left: The lunar Alps and Caucasus Mountains almost meet to form a ''barrier'' between Mare Serenitatis (left) and Imbrium. Photo by Jean Dragesco (14-inch SCT, Ektachrome 200 film) Top: The southern highlands near Clavius and Tycho; photo by John Steenkamp (20-cm telescope, 1-second exposure at f/40 on Fuji R100 film). Above: Gassendi crater lies on the northern edge of Mare Humorum; photo by Bob Funanage (8-inch SCT, 1 second at f/110 on VR 200). Right: The highlands region near Walter. Photo by Jean Dragesco (14-inch SCT, 1-second exposure at f/60 on Ektachrome 400 film).



Left: A two-day-old Moon with Earthlight; note the detached mountains near the southern cusp. Photo by Jim Baumgardt who used a 10-inch Newtonian and a 1/15-second exposure at f/5 on Kodachrome 64 film. Above: The ancient ring-plain Deslandres. Photographed by R.J. Stuart at f/140 with an 8-inch SCT and Tri-X film.

factor = (D/E) + 1

where D and E are as before. A Barlow's focal length is provided by the manufacturer; in computing the projection factor, ignore the minus sign on the focal length figure and treat it as a positive number in the equation.

Luckily, you only have to thrash through these numbers once with each telescope and eyepiece combination. When worked out, write down the factors for each eyepiece/telescope combination in waterproof ink on an index card and keep it with your astrophotographic gear.

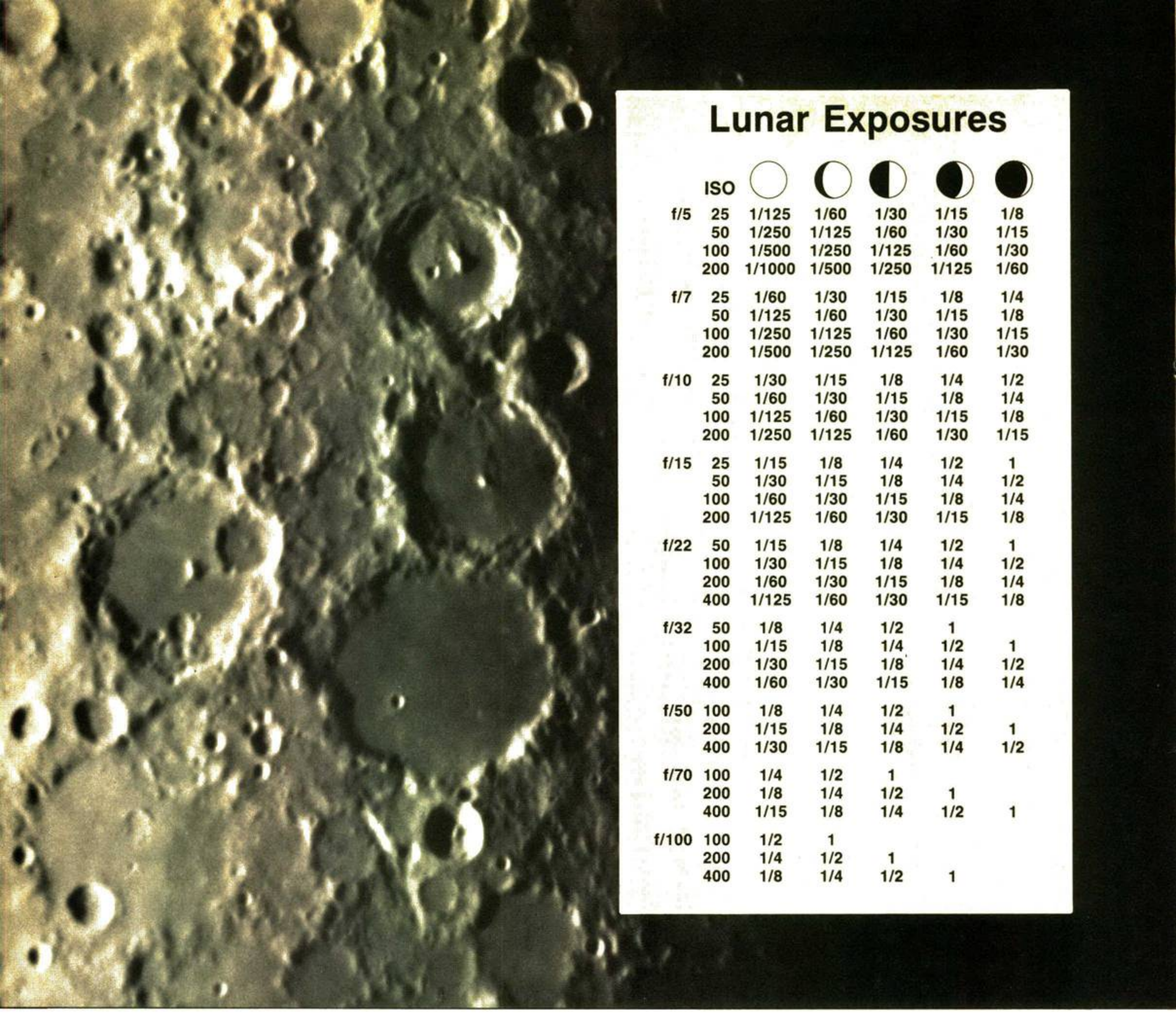
After you have the e.f.r. of the system, turn to the lunar exposure table on page 76 to find the proper exposure time for any given film and lunar phase. This table gives a good starting point for bracketing exposures a stop or two on either side.

Curious to know how big the Moon's image will be on the negative? Just divide the e.f.l. by 115. With an e.f.l. of 1800mm, the Moon's diameter is 16mm on the negative. (Using fine-grain film, an image this size can be enlarged to make a good 5x7 print.) With the 6-inch scope and the 12mm eyepiece of the other example, the Moon comes out 123mm across — so big that only part of its surface can be recorded at a time.

Steady Seeing Is Vital

After adequate focal length, seeing — how settled the atmosphere is — becomes the chief determinant of how much lunar detail you can photograph. If the seeing isn't at the 1 second of arc level or better, your photos just aren't going to be very sharp — at least at high magnifications. When the seeing is good but not excellent, keep the magnifications low and try for whole-disk shots. Once you've "broken in" your gear and become proficient at handling it in the dark, back off a bit. Become more critical of seeing quality and learn to wait for the really good nights, when you can put all of your equipment and skills to best use.

Apart from bad seeing, vibration from an SLR's mirror causes most of the unsharp pictures in high-resolution astrophotography. To eliminate this as a source of blurry photos, try the following: set the camera to B or T, focus on the Moon, and cover the telescope's aperture with a piece of stiff black cardboard. Then trip open the



Lunar Exposures

	ISO	○	🌔	◐	🌒	●
f/5	25	1/125	1/60	1/30	1/15	1/8
	50	1/250	1/125	1/60	1/30	1/15
	100	1/500	1/250	1/125	1/60	1/30
	200	1/1000	1/500	1/250	1/125	1/60
f/7	25	1/60	1/30	1/15	1/8	1/4
	50	1/125	1/60	1/30	1/15	1/8
	100	1/250	1/125	1/60	1/30	1/15
	200	1/500	1/250	1/125	1/60	1/30
f/10	25	1/30	1/15	1/8	1/4	1/2
	50	1/60	1/30	1/15	1/8	1/4
	100	1/125	1/60	1/30	1/15	1/8
	200	1/250	1/125	1/60	1/30	1/15
f/15	25	1/15	1/8	1/4	1/2	1
	50	1/30	1/15	1/8	1/4	1/2
	100	1/60	1/30	1/15	1/8	1/4
	200	1/125	1/60	1/30	1/15	1/8
f/22	50	1/15	1/8	1/4	1/2	1
	100	1/30	1/15	1/8	1/4	1/2
	200	1/60	1/30	1/15	1/8	1/4
	400	1/125	1/60	1/30	1/15	1/8
f/32	50	1/8	1/4	1/2	1	
	100	1/15	1/8	1/4	1/2	1
	200	1/30	1/15	1/8	1/4	1/2
	400	1/60	1/30	1/15	1/8	1/4
f/50	100	1/8	1/4	1/2	1	
	200	1/15	1/8	1/4	1/2	1
	400	1/30	1/15	1/8	1/4	1/2
f/70	100	1/4	1/2	1		
	200	1/8	1/4	1/2	1	
	400	1/15	1/8	1/4	1/2	1
f/100	100	1/2	1			
	200	1/4	1/2	1		
	400	1/8	1/4	1/2	1	

shutter with a cable release, wait a few seconds to let the vibrations die out, and remove the cardboard to begin the exposure. When you want to end the exposure, cover the aperture with the cardboard, release the shutter, and wind on to the next frame. The cardboard trick can give consistently accurate exposures down to 1/10th second. (For speeds faster than that, use the camera's internal shutter and try to lock up the mirror.) Be careful not to let the cardboard touch the end of the scope or you'll initiate the very vibrations you're seeking to avoid.

Choosing the Right Film

What about film? Almost any will do because the Moon is a bright subject. But anyone trying to use an alt-azimuth mounted scope should opt for the faster emulsions despite their graininess, since exposure times will be shorter. Traditionally, lunar photography has been black & white, but today many people use color film, with varying results. The Moon's natural color is very subtle, but anyone viewing a warm-tinted transparency of the First Quarter Moon will probably find it quite evocative regardless.

On the other hand, color film has pitfalls — which you'll discover when you get your first ugly-green Moons back from the processor. As done by commercial photofinishers, color prints tend to come out too light overall. It's best to take your film to a "1-Hour Photofinisher" and explain what you're looking for to whoever will be making the print.

Assuming you can handle long exposures, the best film overall is Kodak's 2415 Technical Pan. It's black & white and abominably slow, even when hypersensitized. But it is virtually grainless and has excellent resolution and contrast. A crisply taken and well-processed negative on 2415 will withstand an astonishing degree of enlargement.

Ptolemaeus, Alphonsus, and Arzachel line up along the eastern shore of Mare Nubium. Photo by L.H. Price, who used a 6-inch Newtonian, a 2-second exposure on SO 115 film (now Technical Pan), and eyepiece projection to f/60.

While no amateur lunar photographer can expect to rival the professionals, you can still take pride in being able to photograph our own Moon — another world out there in space — even through a small backyard telescope. And each picture will become a memento of a splendid evening or dawn spent gazing at its varied terrain, its rocks, mountains, and craters.

David McConnell is a professional meteorologist and amateur astronomer with a strong interest in astrophotography. He lives in Inverness-shire, Scotland.

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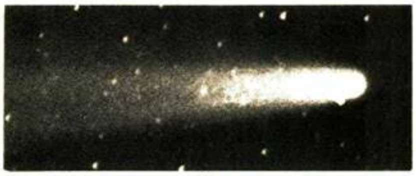

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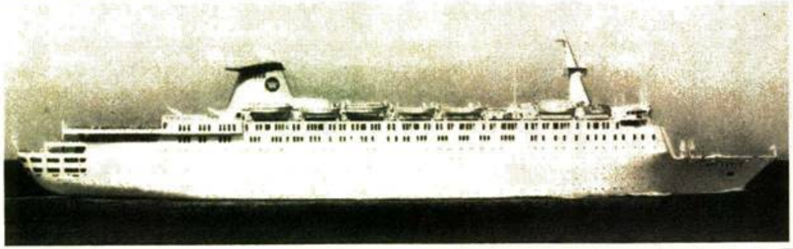

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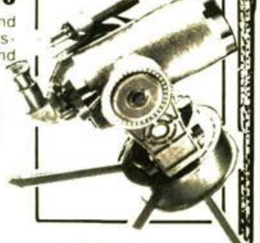

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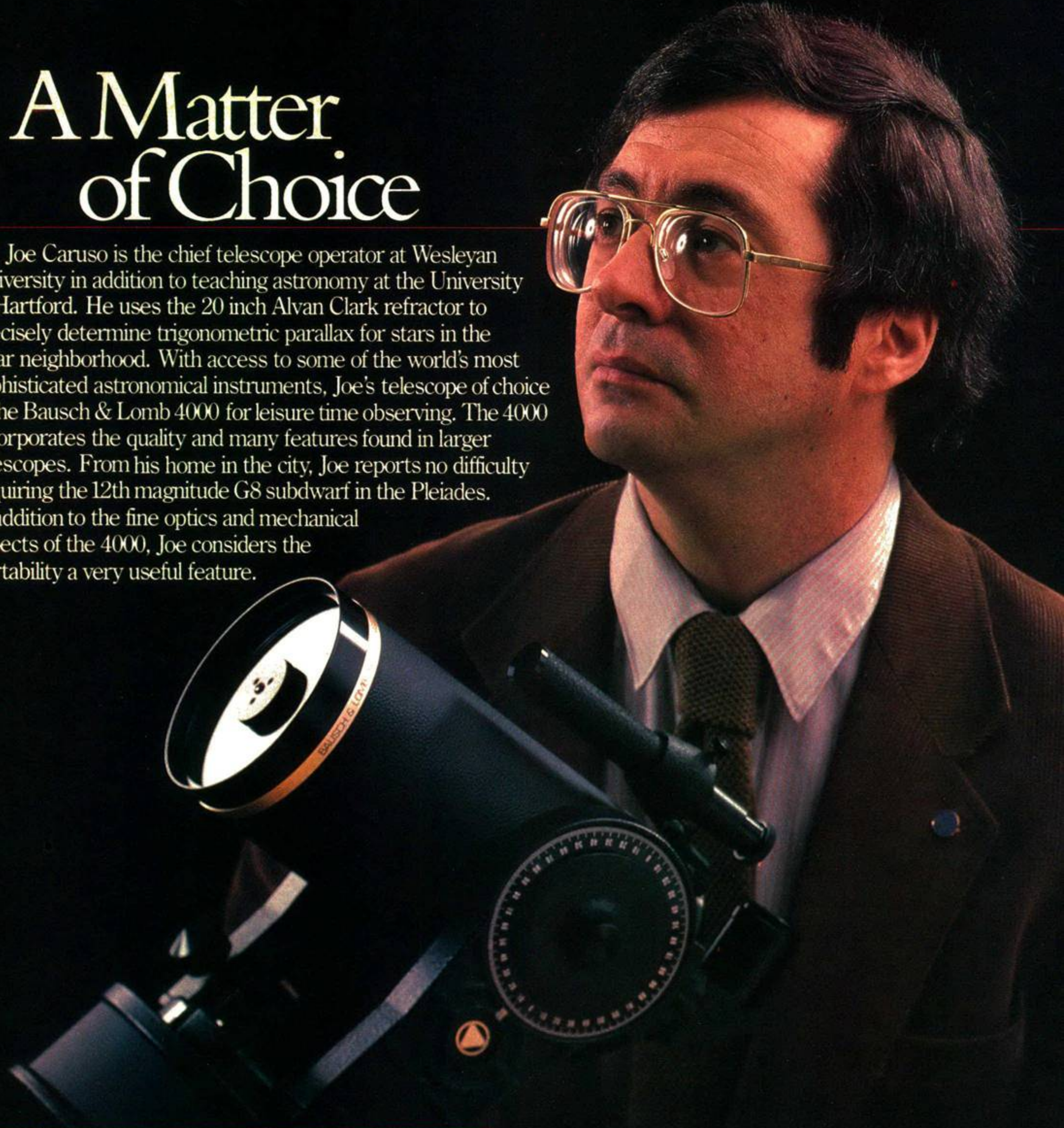
Joe Caruso is the chief telescope operator at Wesleyan University in addition to teaching astronomy at the University of Hartford. He uses the 20 inch Alvan Clark refractor to precisely determine trigonometric parallax for stars in the solar neighborhood. With access to some of the world's most sophisticated astronomical instruments, Joe's telescope of choice is the Bausch & Lomb 4000 for leisure time observing. The 4000 incorporates the quality and many features found in larger telescopes. From his home in the city, Joe reports no difficulty acquiring the 12th magnitude G8 subdwarf in the Pleiades. In addition to the fine optics and mechanical aspects of the 4000, Joe considers the portability a very useful feature.



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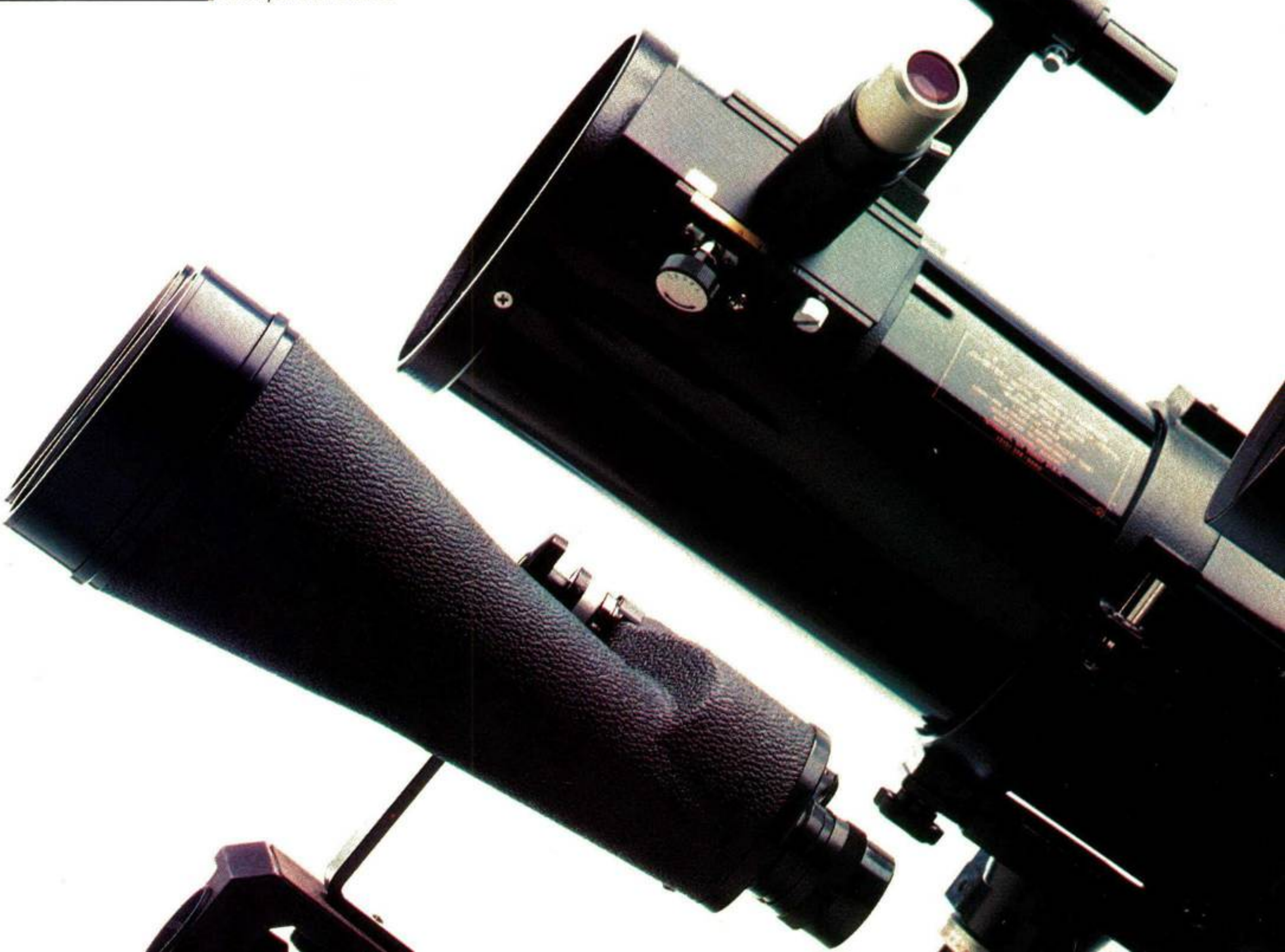

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ASTRO NEWS

Jupiter Has a New Ring

By analyzing photos taken in July 1979 during the Voyager 2 flyby of Jupiter, astronomers Mark R. Showalter and Joseph A. Burns of Cornell University and Jeffrey N. Cuzzi and James B. Pollack of NASA's Ames Research Center have discovered an additional ring around Jupiter.

Dubbed the gossamer ring, the new feature lies just outside the already-known bright ring. This discovery, reported in the August 8th issue of *Nature*, will force re-routing of NASA's Galileo space probe scheduled to leave for the giant planet this spring.

"The gossamer ring's particles are in the micron (one millionth of a meter) range, about the size of smoke particles," says Burns. "Because the particles orbit in the jovian Van Allen belt (an area of intense electro-magnetic radiation), they are probably 'eaten away' in 100 to 1,000 years, and we believe the ring is being fed constantly by larger chunks of material."

So far, no large chunks have been detected in the third ring, according to Showalter. "The entire ring system seems to be composed for the most part of micron and sub-micron-sized particles," he says, "but, of course, larger parent bodies must also exist."

Concern that the ring's particles could penetrate the heat shield of the Galileo probe prompted the astronomers to advise NASA that a detour was in order. The probe, which will separate from the Galileo orbiter after launch, was to pass through the region occupied by the gossamer ring before diving into Jupiter's atmosphere. Even small holes in the heat shield could cause heat surges and cripple the probe's delicate instruments. As a result, NASA will re-route the spacecraft away from the ring region.

Unequivocal evidence of the gossamer ring was found in only one Voyager image, made when Voyager 2 was in the shadow of Jupiter.

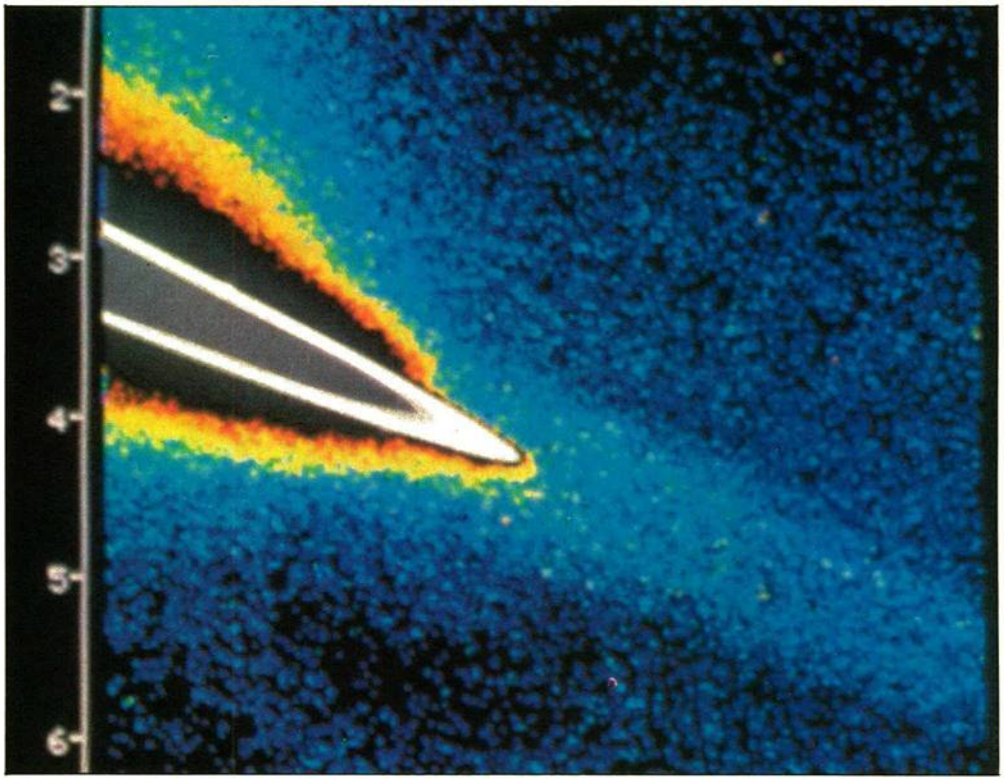
"This particular image has already received extensive scrutiny so it may seem surprising that the ring was overlooked," say the astronomers. With the help of Cuzzi and Pollack, Burns and Showalter re-processed the data to subtract all background noise in the image.

"In retrospect, the additional ring was hinted at in earlier Pioneer 10 and 11 data," the astronomers note. "Pioneer 10's meteoroid impact detector recorded at least one event near ring-plane crossing at a distance of 206,000 kilometers, well outside the bright ring but within the gossamer ring." The gossamer ring extends some 210,000 kilometers from the planet.

The new ring is about 20 times fainter than the bright ring, which itself is so faint that it can be seen only by the very largest Earth-bound telescopes. The dark-colored particles in the ring are probably red due to a coating of sulfurous material from volcanoes on the jovian moon Io, according to Burns.

The astronomers speculate that two of Jupiter's 16 known satellites, Amalthea and Thebe, may be sources of particles for the gossamer ring. Micro-meteoroids striking the surface of either or both satellites, which orbit in the ring's outer region, may be injecting dust into the ring system.

Besides providing another feature for Galileo to observe when the spacecraft arrives in 1988, Burns predicts that the discovery of the ring will likely send astronomers back to the Voyager 1 and 2 data on Saturn, home of this solar system's most elaborate ring system.



The new jovian ring appears as the broad blue streak extending diagonally across the photo to the lower right. Other known rings are the bright ring (shown in white) and the halo (outlined in red-yellow). Photo courtesy Mark R. Showalter, Cornell University.

Giotto II?

In March 1986, the Giotto spacecraft will plow through Comet Halley's thick coma of gas and dust. Thanks to the extremely high encounter velocities, all the spacecraft's experiments must be done within minutes, seriously limiting what can be accomplished.

Now, European and American scientists are considering using spare parts from Giotto to construct a spacecraft to bring back a sample of a comet's coma. Writing in the *Journal of the British Interplanetary Society*, P. Tsou of the Jet Propulsion Laboratory, D.E. Brownlee of the University of Washington, and A.L. Albee of the California Institute of Technology suggest that such a mission could be accomplished by a Giotto-class spacecraft using a "free-return" trajectory.

The proposed European-built Giotto II with American sample-collection equipment would be launched from the Space Shuttle directly into an orbit which, after the probe had flown past the target comet, would return again to Earth with no major maneuvers along the way.

Collectors on the front of the spacecraft would gather cometary material as it flew through the comet's coma. Once Giotto II returned to the vicinity of Earth, an on-board rocket would slow the craft for retrieval by the Shuttle. The spacecraft could also eject the samples in a re-entry capsule like those used to return film from military observation satellites.

For simplicity, only passive collectors are being considered, possibly an array of hollow cells. When a comet particle penetrated a cell it would largely vaporize, but part of the vapor would condense on the inside of the cell and could be analyzed upon return to Earth.

Another sampling method would involve a metal foil. When Shuttle astronauts repaired the Solar Maximum Mission spacecraft in Earth orbit, they retrieved some of the satellite's foil thermal blanket to see how it had fared. The foil was pitted with hundreds of impacts and in many of the microcraters, scientists found parts of the impacting objects, indicating that comet samples could also be obtained this way.

A third method might use an "underdense" material such as polystyrene foam to slow and capture any particles striking it. The advantage of this is that at least part of the particle may be captured intact, allowing studies of its structure and composition.

A fourth method would capture gas from the coma with a chemically-reactive surface, though this technique is particularly

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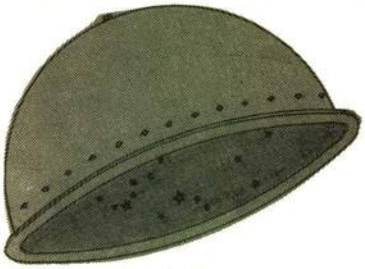

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ASTRO NEWS

susceptible to contamination. The authors suggest that contamination can be minimized by carefully selecting the material the collectors are made of. If the mission does fly, it's likely that a combination of some or all of these techniques will be used.

Obviously, the slower the spacecraft travels with respect to the target comet, the more and better the samples. The authors calculate that given a launch energy of less than 100 kilometers per second and a comet perihelion date between 1988 and 2000, up to 73 periodic comets can be visited within 50 days of perihelion using a minimum energy trajectory. Encounter speeds generally range between 10 to 20 kilometers per second, but increasing the launch energy can reduce this in some cases. With modest improvements to Giotto's camera, optical navigation might allow a "slow" flyby to within 80 kilometers of the nucleus.

The authors conclude that despite budget problems on both sides of the Atlantic, "Giotto II is a unique opportunity for first-class science using both *in situ* instrumentation and a first-time coma sample return. Giotto II is very low-cost. Such a NASA/European Space Agency cooperative mission should not be missed by the global science community." *Donald F. Robertson.*

Insurance Problems May Impede Space Commercialization

As American industry becomes increasingly interested in the potential profits of space commercialization, the cost and availablity of space insurance may prove to be a serious impediment.

The insurance industry has been concerned about the profitability of space insurance since the late 1970s. But the space community, especially those companies interested in putting satellites into Earth orbit, only became aware of the problem in early 1984, when two satellites launched from the Space Shuttle didn't reach proper orbits after booster engines failed. These satellites, Indonesia's Palapa 2-B and Western Union's Westar VI, were insured for a total of $180 million. And the following June, a ground-launched booster failed to place the Intelsat V F-9 satellite into its geostationary orbit. Insured for $102 million, this claim brought the total net loss for the insurance industry to $282 million in the first half of 1984.

There were no further losses in 1984, and both the Palapa and Westar satellites were successfully recovered by the Shuttle late that year. The salvage operation was possible, however, only because both satellites were in orbits that could be safely approached by the Shuttle. With most satellites, that is not the case.

While some confidence returned after several successes with the same booster design that had failed on the earlier Shuttle launches, potential problems still loom ominously. Faced with such huge losses, many insurers have pulled out of the market and others are predicting much higher rates.

After the Palapa and Westar failures, insurers expected premiums to rise from the prevailing rate of 5% or 6% to 25% or 26% of the cargo's insured value; some expected even higher rates. A more optimistic report speculated that rates for Shuttle-launched satellites could rise to about 20% of the insured value, and rates for the European Space Agency's Ariane launcher could be several percentage points higher.

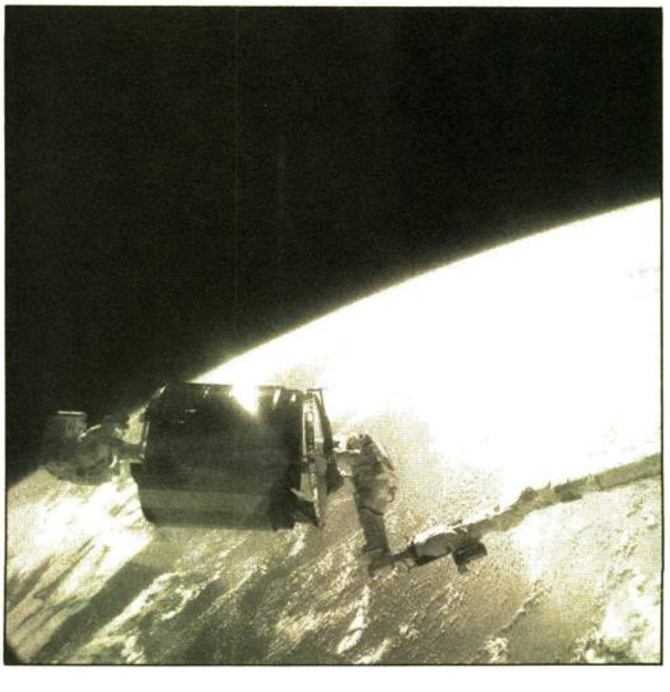
Other insurance industry sources now report that Shuttle rates have already increased to 14% to 16% of insured value. In early 1985, premiums for Ariane launches were reportedly offered at 15% to 16%, an increase of three or four percentage points. However, record premiums of 20% were paid for the February 1985 Ariane launch of Arabsat and Brazilsat satellites. Ariane rates are generally higher because this is a newer and less proven launch system than the Shuttle.

Few companies provide insurance for satellites and at least two dropped out of the market after the 1984 disasters. These problems are expected to continue, according to a study by the Congressional Research Service for the U.S. Senate Committee on Commerce, Science, and Transportation. The March, 1985 study, *Insurance and the Commercialization of Space,* explains that while demand for space insurance is increasing, the sources of underwriting coverage have declined because of six consecutive years of losses among insurers.

According to an April 1985 report of the Aerospace Industries Association of America, Inc., the industry reported a net loss ratio for space insurance of 208% from 1979 through 1983. The report, *A Current Perspective on Space Commercialization,* noted that with such losses, insurance rates would have to double to reach the break-even point.

Several alternative plans have been suggested to help deal with space insurance problems. One involves co-insurance, where the client company assumes some of the risk. Another possibility is increased satellite deductibles, which would allow a client to collect for damages only after one or more in a series of satellites is lost. Additionally, insurers could offer specific coverage for certain parts of the satellite or satellite-launch system.

Perhaps the U.S. Government will become an insurer of "last resort." However, a U.S. Senate committee study maintains that the government should not permanently enter the insurance business. The study concluded that "any government intervention in the market might be introduced with an eye to phasing it out and returning the coverage to the private market . . . . Such a development might become possible as the industry matures further and technology becomes more stable." *Ray Grasshoff.*



Astronauts Dale A. Gardner (left) and Joseph P. Allen maneuver a damaged Westar VI/PAM-D satellite into the Shuttle *Discovery* in 1984.

NGC-7603 and 7603B: An Enigmatic Galaxy Pair?

NGC-7603 and NGC-7603B, two faint galaxies in the constellation Pisces, are currently puzzling astronomers. The two galaxies appear to be physically linked by a luminous connection of intergalactic matter, yet their redshifts differ considerably. Spectra from the two galaxies indicate that 7603B, the smaller companion, is moving away from us at some 16,000 kilometers-per-second as compared to the 8,000 kilometers-per-second velocity of the larger galaxy NGC-7603. This seems to place 7603B trillions of miles into the background.

Because of this dilemma, astronomers are closely examining NGC-7603 and 7603B to determine whether they are physically related; if so, the pair offers a seeming contradiction to the concept of redshift-distance measurement.

These galaxies are prime examples of the simmering controversy over redshifts — the displacement of an object's spectrum toward the longer, redder wavelengths as it travels away from an observer. In an expanding universe, everything moves away from everything else — the faster the speed of recession, the farther away an object. Most astronomers accept redshift as an indicator of recession velocity and, consequently, distance. But the debate questions whether redshifts are reliable as distance indicators.

A recent study by Nigel Sharp, an astronomer at Kitt Peak National Observatory, has provided strong evidence that the two galaxies are *not* linked and that their velocity differences are just what they seem to be. According to Sharp, NGC-

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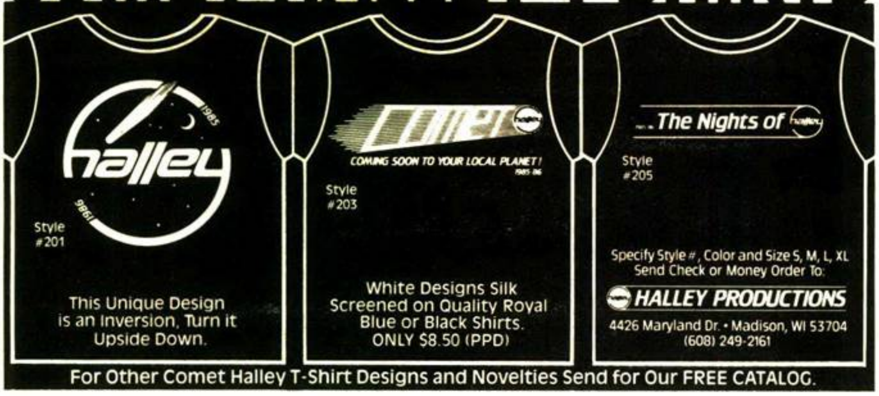

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ASTRO NEWS

7603 and 7603B provide "perhaps the most convincing case of associations between galaxies of greatly different redshifts" — that is, their existence is one of the strongest arguments against a cosmological interpretation of redshift.

For his study, Sharp used photographic plates taken of the two galaxies along with observations made on the 1.3-meter and 4-meter telescopes at Kitt Peak. He also used computer modeling techniques to enhance the detail in the images of 7603B. These images show that 7603's luminous arm, which appears to end exactly at the smaller galaxy, in fact extends past 7603B and that there are other less bright arms also reaching out from the larger galaxy.

The argument favoring an association between the two galaxies, Sharp notes, is based mainly on their appearance. Besides the bridge that seems to link them, the larger galaxy has a bright and active Seyfert-type nucleus. This indicates that something — possibly tidal interactions with a companion — has awakened the dormant core. But Sharp says several galaxies near the "pair" have about the same redshift as 7603, suggesting that they may have once been associated with it and that possibly a member of the group was ingested by 7603. This could explain the highly active appearance of 7603, he says, better than it does interaction with 7603B.

Sharp also notes that the apparent structure and derived absolute magnitude of 7603B are "only really acceptable for a background object" because companions to active galaxies have either been stripped to their cores by the tides of the larger galaxy's gravitation or have a "broad, diffuse appearance." Therefore, 7603B cannot be a companion to 7603. Or can it?

Having come close to proving that 7603B must be a background galaxy, Sharp explains that its absolute magnitude would also be appropriate for a dwarf elliptical companion galaxy. And he notes another persistent ambiguity: the velocity dispersion — the spread of velocities of individual stars — within 7603B appears to be only about 100 miles per second. While this is not low enough to contradict the evidence of 7603B's redshift, it is lower than one would expect at the indicated cosmological distance.

While Sharp's observations strongly suggest that 7603B poses no real threat to cosmological interpretations of redshift, he cannot absolutely rule out some linkage between the two galaxies.

Spaced-Out Ideas Sought by Institute

The National Space Institute is seeking ideas from the general public on potential uses of space — what the United States should be doing in Earth orbit and beyond, now and in the future — that will benefit mankind.

According to the Institute, the program, called *Space Outreach '85*, is meant "to broaden, in a modest way, what appears to be a much too narrow debate as to our long-term civilian space goals."

All ideas will be presented to Congress, the National Aeronautics and Space Administration, and the National Commission on Space. Entries will be reviewed by a panel of judges including Walter Boyne, Director of the Smithsonian's National Air and Space Museum; Evert Clark, Technology Editor of *Business Week* magazine; former astronaut Michael Collins; and Robert Cowen, a science writer for *The Christian Science Monitor*. The author of the most innovative suggestion will receive an all-expense paid trip to watch a Space Shuttle lift-off.

Entry requirements for *Space Outreach '85* state that submissions "should be creative, innovative, and feasible" but "should not include scientific or exploration projects such as Moon bases or Mars missions, as these are already under review by the federal government." Entries can not be more than 750 words long and must by received by December 1, 1985.

For further information or to submit an idea, contact Space Outreach '85, The National Space Institute, West Wing Suite 203, 600 Maryland Ave., S.W., Washington, DC 20024, phone (202) 484-1111.

Dial-A-Comet

On September 3rd, the U.S. Naval Observatory began a dial-in phone service to provide current information on Halley's Comet. The phone number, accessible 24 hours a day, is (202) 653-0258. The messages, written at a popular level and biased for the Washington, D.C. area, will be updated as frequently as necessary.

ASTRO CALENDAR

December 6-7
Comet Quest: An International Symposium, Albert Einstein Planetarium, National Air and Space Museum, Smithsonian Institution, Washington, D.C. A comet party will also be held on December 6 featuring a lecture by Carl Sagan in the Langley Theatre. Contact: Visitor Information Center, Smithsonian Institution, Washington, DC 20560. Phone (202) 357-2700.

December 13-15
Winter Star Party, sponsored by the Arkansas/Oklahoma Astronomical Society, Sallisaw Creek Recreation Area, Oklahoma. Contact: Bob Moody, 109 S. Cedar, Sallisaw, OK 74955. Phone (918) 775-3739.

February 7-10, 1986
Second Annual Winter Star Party, sponsored by the Southern Cross Astronomical Society, Everglades National Park, Florida. Contact: Pat D'Auria, 1051 N.W. 145 St., Miami, FL 33168. Phone (305) 685-6001.

March 26-29
National Convention of the National Science Teachers Association, San Francisco, California. Contact: Matthew R. Murphy, NSTA, 1742 Connecticut Ave., N.W., Washington, DC 20009. Phone (202) 328-5800.

April 18-19
Wisconsin Society of Science Teachers Annual Spring Convention, Appleton, Wisconsin. Contact: Floyd R. Henschel, 504 W. Maple Ave., Beaver Dam, WI 53916. Phone (414) 885-4415 weekdays or (414) 887-1215 evenings.

April 19
Astronomy Day. For more information, contact: Gary Tomlinson, Astronomy Day Coordinator, Astronomy League, Chaffee Planetarium, 54 Jefferson S.E., Grand Rapids, MI 49503. Phone (616) 456-3985.

May 5-10
Texas Star Party, Prude Ranch, Fort Davis, Texas. Contact: Carol Rodgers, 128 N. Commerce, Burleson, TX 76028.

June 22-26
168th Meeting of the American Astronomical Society (professional meeting), sponsored by Iowa State University, Ames, Iowa. Contact: AAS, 1816 Jefferson Pl., N.W., Washington, DC 20036.

June 29-July 4
International Planetarium Society Eighth Biennial Conference, Tucson, Arizona. Contact: IPS Conference Committee, Flandrau Planetarium, University of Arizona, Tucson, AZ 85721. Phone (602) 621-4515.

August 5-10
AstroCon 86 (national convention of the Astronomical League), Baltimore, Maryland. Contact: Astro-Con 86, 642 Kingston, Rd., Baltimore, MD 21220.

Meeting notices to appear in AstroCalendar must be submitted at least four months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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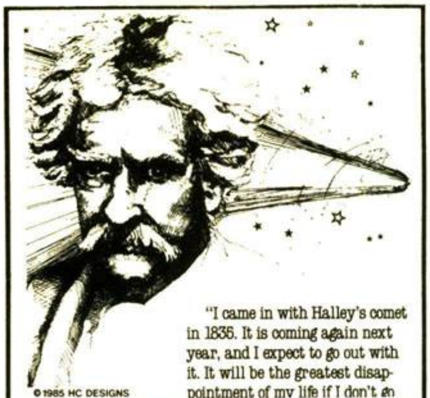
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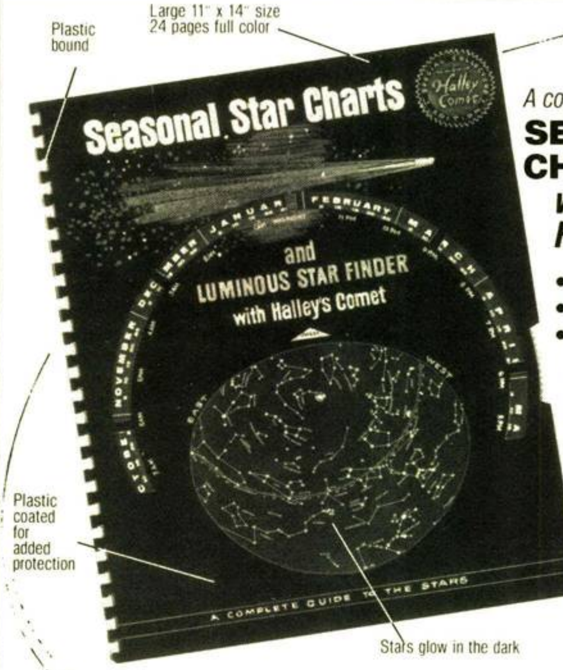

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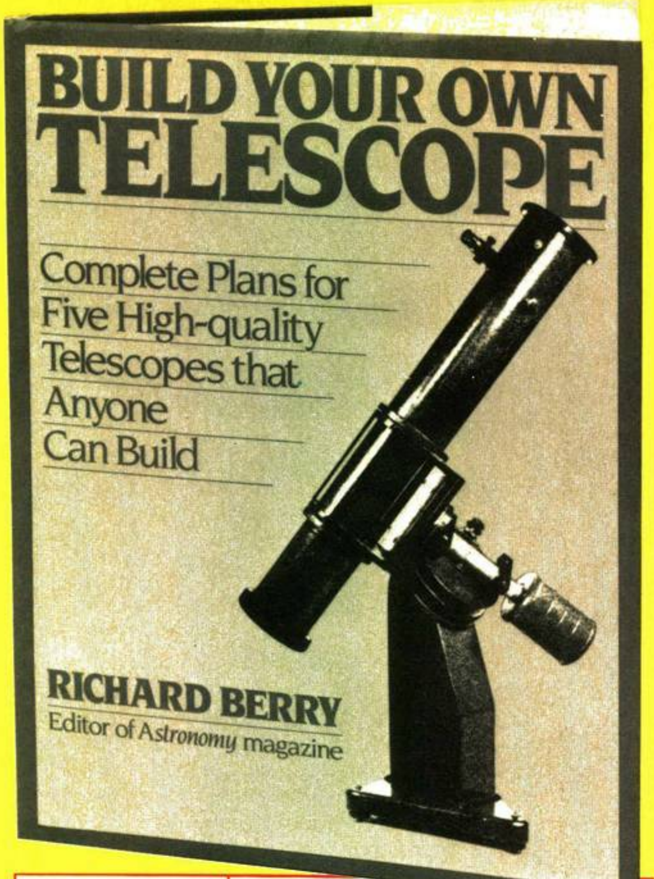
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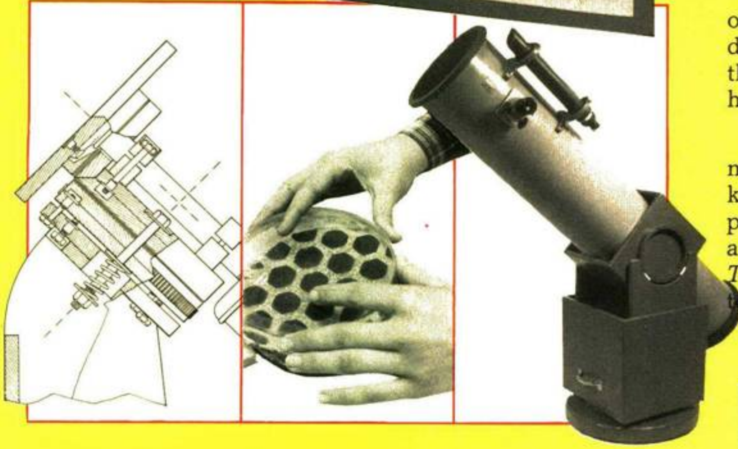

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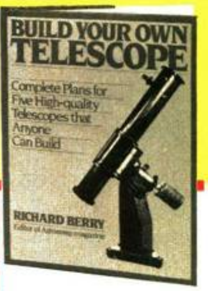
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THE HERBIG STARS

by John K. Davies

When astronomers talk of how stars form, they very often refer to T Tauri stars. Named for the prototype object, T Tauri stars are irregular variables associated with dark clouds of dusty gas and are believed to be less than a million years old. They are still contracting toward the main sequence.

Because the central core of a T Tauri star isn't hot enough to burn nuclear fuel, all the energy it gives off comes from the release of potential energy as the star contracts under its own gravity. Most of the energy released this way is carried to the surface by convection currents in the star's gaseous atmosphere. Not until the core temperature rises high enough to begin nuclear fusion, and energy transportation becomes dominated by radiation, does the star evolve from the T Tauri phase into a normal main sequence star.

This model has become so popular among astrophysicists that the expression "T Tauri phase" is now synonymous with pre-main sequence evolution. Yet this is rather unfortunate, since T Tauri stars are low-mass objects; they have around 0.5 to 3 times the mass of the Sun and will finally reach the main sequence as stars of spectral types F, G, or K. Thus a T Tauri star cannot be the progenitor of a hot massive star of spectral type B or A, which weighs in at 5 to 10 solar masses. To find very young examples of these more massive stars, we must search for stars of spectral type B or A, but with properties similar to those of the T Tauri stars.

The first attempt to identify such young, massive stars was made by astronomer George Herbig, who published a survey of 23 candidates in 1960. Herbig picked stars of spectral types A and B which were associated with nebulosity and whose spectra displayed emission lines. He found evidence that these stars were surrounded by circumstellar shells and possessed strong stellar winds. Although at the time he published his results Herbig did not believe he had conclusively identified massive pre-main sequence stars, follow-up work by other astronomers has confirmed his hunch. This class of objects is now known as the Herbig Ae/Be stars (the "e" stands for emission).

Herbig's stars clearly represent an important stage in the evolution of massive stars and have been studied intensively over the past two decades. But despite these efforts, many questions remain unanswered, perhaps the most crucial being the cause of the optical variability found in many of them. A full understanding of this variability is important because of the clues it provides to processes occurring in the atmospheres and *circumstellar* shells of these stars.

In the optical part of the spectrum, the Herbig stars may vary as much as four magnitudes, although they frequently vary less than that and in some cases no variability is found. The stars that show the most extreme range of brightness usually exhibit a small-scale variability of a few tenths of a magnitude with occasional large brightness changes superimposed on this general background. The large changes often occur very suddenly, the star fading perhaps two magnitudes during a single night and returning to its original brightness just as quickly a day or two later. It is these dramatic changes which make Herbig stars so interesting and difficult to understand.

The discovery that many Herbig stars were brighter at near-infrared wavelengths than would be expected for a typical A or B star — or, as an astronomer would say, have an "infrared excess" — has raised the possibility that these stars are surrounded by shells of dust as well as gas. The dust would be warmed by the central star and would emit infrared radiation, producing the observed excess.

Orbiting dust could also explain the optical variability if we imagine that the dust is not evenly spread around the star but is clumped. Whenever a particularly dense patch of dust passes in front of the star, an eclipse occurs, producing the rapid fading and equally rapid brightening.

But one of the difficulties with this dust-obscuration theory is that it requires material to be orbiting the star in a sort of protoplanetary disk and that we view this disk almost edge-on. Unless the Earth lies almost exactly in the correct line of sight, we wouldn't see any eclipses by the orbiting material; and while it might be possible to explain a few cases this way, it's very unlikely that the correct viewing geometry exists for *all* the variable Herbig stars.

An alternative suggestion that removes the need for special observing conditions proposes that dust is condensing from material in the powerful stellar winds known to be associated with stars of this type. As the stellar wind drives material away from the star in all directions, the material cools and eventually condenses to form grains that dim the light from the central star. In this model, fluctuations in the stellar wind produce variations in the condensing dust around the star, and this creates the optical variability. But whether condensations could form and disperse quickly enough to explain the observed rapid brightness declines and recoveries is open to question.

Difficulties with these dust explanations have led other astronomers to favor a model in which the variability is due to changes in the emission from the star's atmosphere, most notably

Describing the creation of large massive stars such as those found in clusters and stellar associations is a major problem for astrophysics. Twenty-five years ago, astronomer George Herbig identified several such stars, but only now are we beginning to understand them. M-8 photo courtesy Caltech.

its chromosphere. The chromosphere is a thin, dense shell of gas found just above the visible disk of a star. It is here that the emission lines found in the spectra of Herbig stars arise, and it may be here that changes in the emission processes, driven by changes in the star's magnetic field, affect the optical brightness.

If this hypothesis is correct, the excess infrared radiation arises not from heated dust but from a process called free-free radiation, which occurs in a hot ionized gas cloud surrounding the star. In free-free emission, a negative electron passes close to a positive nucleus and, losing some energy in the encounter, emits a photon of infrared energy before escaping back into free space (see box on page 94).

A different mechanism proposed to explain the variability requires changes in the visible surface of the star — its photosphere. In simple terms, this model uses the rapid formation and decay of huge "starspots" to explain the brightness fluctuations. Several types of spotted stars are known (see "Starspots," ASTRONOMY, February 1983), but these produce a quasi-periodic variability as the star rotates, alternately exposing many or few spotted areas. The changes in the Herbig stars, however, are both irregular and dramatic, and would require the rapid formation of starspots large enough to cover the visible face of the star almost completely. In a case like this, the formation of the spot can almost be regarded as a brief change of spectral type, with the star moving downward and to the right of the main sequence. Suppression of the light from the photosphere in this way would also increase the relative contribution of the chromosphere to the star's visible output, emphasizing the chromospheric emission lines.

Well, how can an astronomer distinguish between the various models? One technique is to monitor the stars photometrically over a period of months to search for trends that correlate with changes in brightness. These observations have been carried out by William Herbst and his collaborators, who began a program of optical photometry from the Van Vleck Observatory in Connecticut, and also by a group of British astronomers that includes Doug Whittet, Nye Evans, and myself, who have used two or more telescopes to monitor Herbig stars at visible and infrared wavelengths simultaneously.

If Herbig stars vary because of obscuration by a dust shell, then they should appear to get redder as they fade. This is because dust particles find it easier to scatter short-wavelength blue light than longer-wavelength red and infrared energy. So when a dust cloud moves in front of a star, the fraction of red light that penetrates the dust becomes greater than that of the blue. Result: the star appears redder than before. Another way of expressing this is that there is a wavelength dependence of magnitude and when the star fades, the blue magnitude changes

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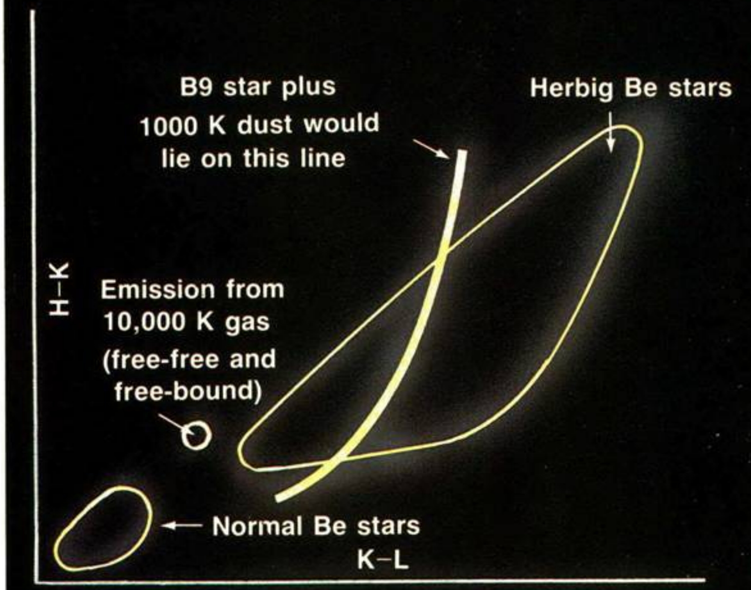
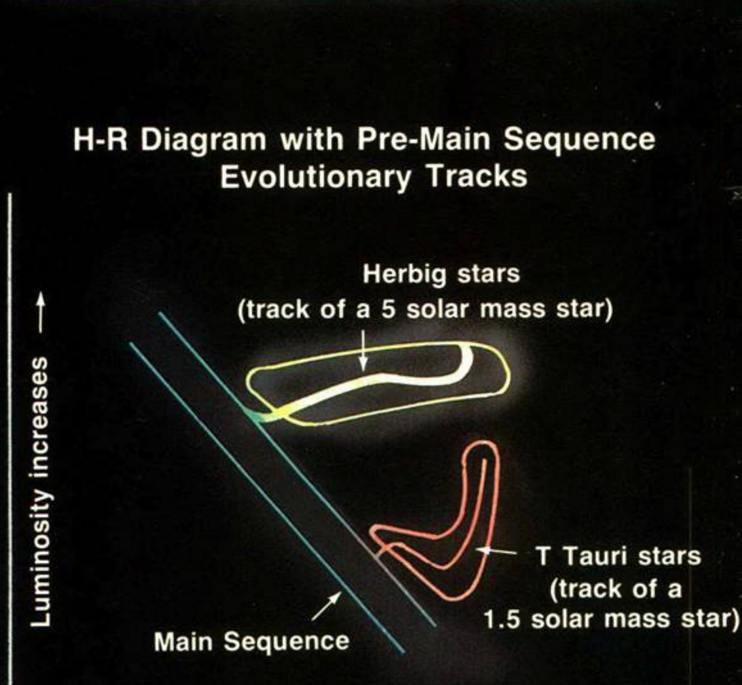


H-R Diagram with Pre-Main Sequence Evolutionary Tracks



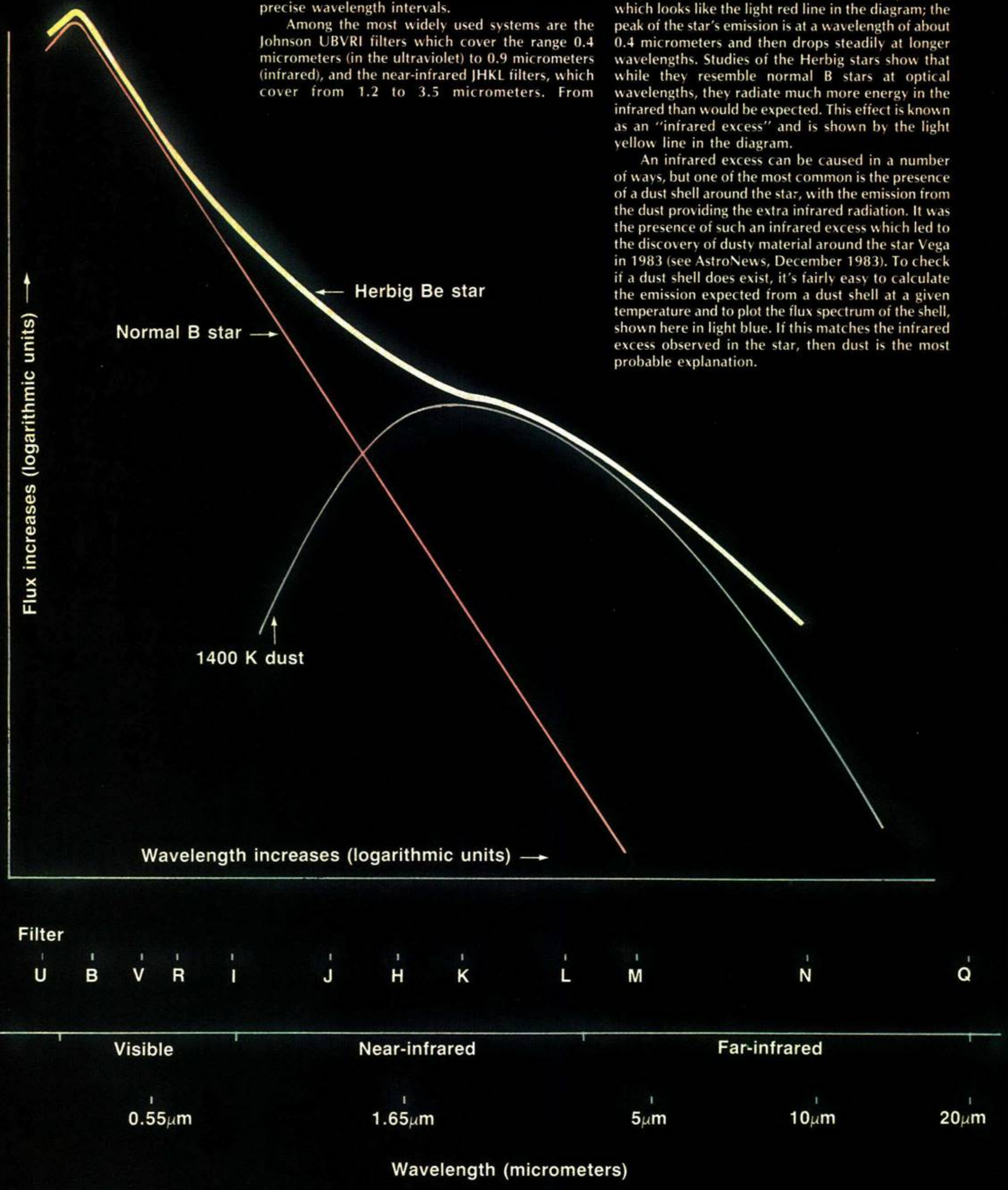
Photometry and Infrared Excesses

Although a practiced eye can judge stellar brightnesses to a tenth of a magnitude, professional astronomers and an increasing number of backyard observers use photoelectric photometry for its greater accuracy. By combining a suitable detector with a selection of wavelength filters, it is possible to measure the brightness of a star over a series of precise wavelength intervals.

Among the most widely used systems are the Johnson UBVRI filters which cover the range 0.4 micrometers (in the ultraviolet) to 0.9 micrometers (infrared), and the near-infrared JHKL filters, which cover from 1.2 to 3.5 micrometers. From photometrically-determined magnitudes, astronomers can calculate the flux (energy) received from a star at the top of the Earth's atmosphere in each of the wavelengths studied and plot the results in what is called a "flux spectrum."

A normal star of spectral type B (surface temperature = 25,000 Kelvins) has a flux spectrum which looks like the light red line in the diagram; the peak of the star's emission is at a wavelength of about 0.4 micrometers and then drops steadily at longer wavelengths. Studies of the Herbig stars show that while they resemble normal B stars at optical wavelengths, they radiate much more energy in the infrared than would be expected. This effect is known as an "infrared excess" and is shown by the light yellow line in the diagram.

An infrared excess can be caused in a number of ways, but one of the most common is the presence of a dust shell around the star, with the emission from the dust providing the extra infrared radiation. It was the presence of such an infrared excess which led to the discovery of dusty material around the star Vega in 1983 (see AstroNews, December 1983). To check if a dust shell does exist, it's fairly easy to calculate the emission expected from a dust shell at a given temperature and to plot the flux spectrum of the shell, shown here in light blue. If this matches the infrared excess observed in the star, then dust is the most probable explanation.



Emission Processes in Stars

In addition to the light emitted from the photosphere, which is due to the high temperatures of its surface layers, a star can produce radiation by a variety of other processes. The most common of these involve interactions between negatively-charged electrons and positive ions in the hot gas which surrounds stars, either in the chromosphere (just above the visible surface of the star) or in a thinner and more extended envelope farther away.

FREE-FREE RADIATION

In very high temperature regions, atoms are stripped of their orbiting electrons. This forms a plasma of positively and negatively-charged particles (ions) in which every particle is moving at very high speed. Each time an electron passes close to a positively charged ion, it is attracted by electrical forces and the path of the electron is bent toward the positive ion. (Strictly speaking, both particles are deflected, but since an electron is tiny compared to the smallest positive ion, we can ignore the effect on the positive ion.) In most cases, the electron will be traveling too fast to be captured and will fly past the positive ion, escaping to continue its independent existence. Nevertheless, during the encounter the path of the electron will be changed, however slightly, and it therefore undergoes an acceleration.

A fundamental law of physics says that when electrons are accelerated, they emit photons which have energies equal to the applied acceleration. In the case of a plasma, this can lead to emission over a range of wavelengths which depends on the temperature. This process is sometimes called Bremsstrahlung emission (from the German word for "braking radiation"), but is more commonly known as "free-free radiation," since the electron starts and finishes the process free of the positive ion.

Because the electrons involved in free-free radiation can approach and leave the positive ion at any velocity, each interaction is unique and produces a photon whose wavelength depends on the exact circumstances of the encounter. In practice, the velocity of the electrons in a plasma is determined by the temperature, so most are traveling at roughly the same speed. This means that a plasma of a given temperature mostly produces radiation in a fairly narrow range of wavelengths. In the case of a Herbig star, this leads to infrared photons, which cause an infrared excess similar to that produced by a dust shell. Astronomers can discriminate between the two processes (free-free or dust) by comparing how the amount of emission varies with wavelength.

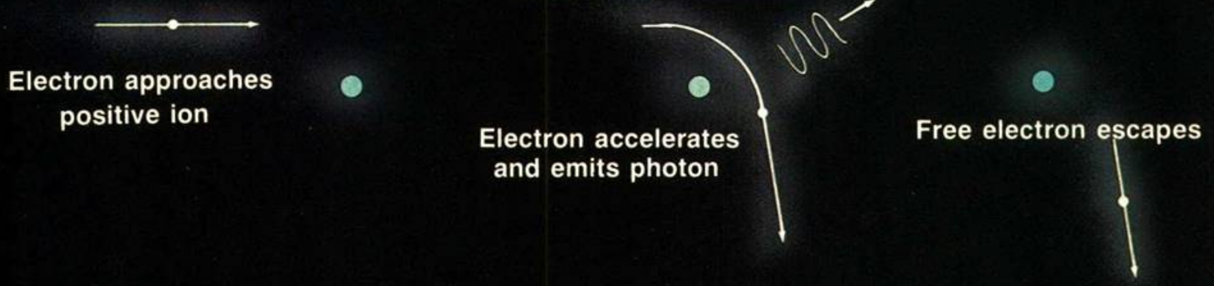
LINE EMISSION

Not all encounters between electrons and positive ions produce free-free radiation. In some cases, the electron is captured by the positive ion, which is usually the nucleus of a hydrogen atom. Electrons that are bound to atomic nuclei are forced to occupy certain specific energy levels and are said to be "quantized" because there is a distinct energy jump, or quantum, which acts as a barrier between the levels.

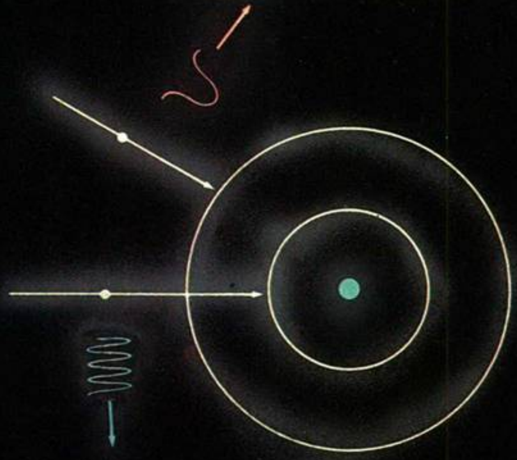
If an electron is captured by a nucleus, it may drop straight down to the lowest energy level, giving up any extra energy it has in the form of a photon. Since the free electrons in the plasma have energies that are not neatly quantized, the photons emitted can have any wavelength, just like in the free-free emission process.

However, rather than going straight into the lowest and most stable level, it's more likely that an electron will be captured into one of the higher energy levels where it can remain for only a short time. Very soon after capture, the electron will try to fall to a lower and more stable energy level and, in the process, will emit energy in the form of a photon. In this case, however, the jump is from one specific level to another, so the electrons *are* quantized and the emitted photon must correspond to the energy difference between the two levels. Since there are only a small number of such jumps allowed, only a small number of wavelengths are emitted and these produce a predictably-spaced series of spectral lines.

Free-Free Radiation

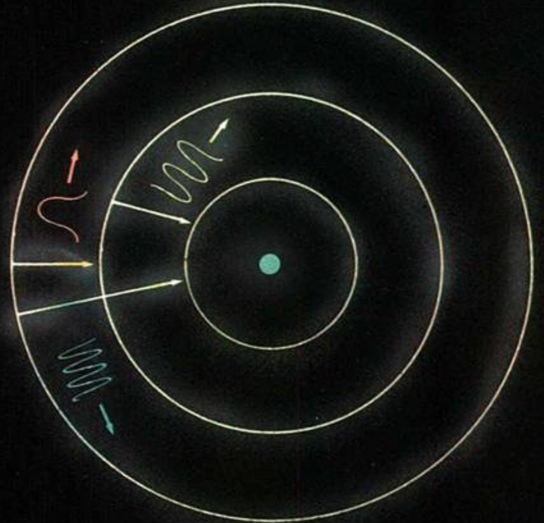

Electron approaches positive ion
Electron accelerates and emits photon
Free electron escapes

Free-Bound Radiation



Free electrons are captured by atom; any wavelength can be emitted

Line Emission



Electrons in upper energy level are unstable; as they fall to lower levels, discrete amounts of energy (quanta) are emitted that produce a line spectrum

Typical Herbig Stars and Similar Objects

Name	R.A. (2000.0)	Dec.	Magnitude	Notes
AB Aur	4h55.8m	+30°33′	7.2-8.4	
UX Ori	5 04.5	− 3 48	8.7-12.8	
T Ori	5 35.8	− 5 28	9.5-12.6	
BF Ori	5 37.2	− 6 35	9.8-13.4	
HD 250550	6 02.0	+16 31	9.7	not variable
Z CMa	7 03.7	−11 33	8.8-11.2	
RY Lup	15 59.5	−40 22	9.9-13.0	T Tauri star
AK Sco	16 54.7	−36 53	8.8-10.3	
XX Oph	17 44.0	− 6 16	9.1-11.1	
TY Cra	19 01.6	−36 53	8.7-12.4	
R Cra	19 01.9	−36 58	10.0-14.0	
MWC 1080	23 17.3	+60 51	13.0	not variable

the most, the red magnitude less, and the infrared magnitude hardly at all, since infrared radiation is very good at penetrating dust clouds. This leads to an important prediction: the trend of increasing redness with decreasing brightness will continue no matter how faint the star becomes.

Herbst and his colleagues believe that at least some of the Herbig Ae/Be stars do not follow this pattern. For example, they found that the star UX Orionis (which varies from about magnitude 9.5 to 11.5) showed a turnaround in its colors as it fades. Although the star seems to follow the "redder when fainter" rule when it dims from maximum brightness, this trend changes as the star falls below about 11th magnitude. Once it is this faint, the color of the star begins to get steadily bluer again as further fading occurs. If these observations are confirmed, they would be difficult to explain in terms of obscuration by dust, but would make sense using the starspot model.

According to this model, the photosphere fades as large starspots form; this increases the relative contribution to the total light output from the chromosphere. Since the chromosphere's light is dominated by emission lines, the brightest of which occur at the blue end of the visible spectrum, it's natural for the star to become bluer as the relative contribution of the chromosphere increases. It is also possible that whatever causes the formation of the starspots (changes in the star's magnetic field, most probably) also produces additional activity in the chromosphere, thus enhancing the blue emission lines even further.

Although the color turnaround reported by Herbst for UX Ori (and possibly also seen in the 10th to 12th magnitude star BF Ori) casts some doubt on the "murky dust" scenario for these stars' variability, there's no doubt whatever that dust *does* exist in the locality of many Herbig stars. The infrared excesses observed for UX Ori and BF Ori can be explained by assuming that these stars are surrounded by shells of dust at temperatures around 1500 Kelvins; similar conditions turn up with most Herbig stars. The temperatures of these shells seem to vary from star to star and range between about 700 K to 1500 K, with a high proportion being hotter than 1200 K.

These high temperatures are surprising because they suggest that the dust shells must be close to the central star, perhaps only 20 to 50 stellar radii distant. It's hard to envision this dust as material left over from the star's formation since the strong stellar winds from Herbig stars would quickly disperse any remaining protostellar nebula. Presumably the dust observed is actually condensing in the stellar wind outflow. Interestingly, similar infrared excesses are found for many of the low-mass T Tauri stars, and the shell temperatures derived for these objects are also high — typically around 1200 K. This observation tends to support the belief that Herbig stars and T Tauri stars are related in some way.

Nonetheless, some astronomers believe that dust shells of such high temperatures are unlikely, and they prefer to explain the infrared excess as free-free radiation. This hypothesis can also be tested and compared to the predictions of the dust shell model using infrared photometry. To do this, astronomers start by defining infrared "colors" as the difference between a star's magnitude as seen through two different infrared filters. For example, subtracting the magnitude at 2.2 micrometers (the K filter) from that at 1.65 micrometers (the H filter) gives the H-K color. Similarly, the difference between the magnitude at 2.2 micrometers and 3.5 micrometers (the L filter) gives the K-L color. Astronomers plot H-K against K-L to make a color-color diagram.

These diagrams are usually drawn so that the reddest objects appear in the top right corner and the bluest objects in the lower right. It is also possible to show on the diagrams the colors expected for normal Be stars, for free-free radiation, and for dust shells of various temperatures (see diagrams on page 93).

The British group studying the Herbig stars has done this and we believe that the infrared colors of the strongly variable stars can *not* be explained by free-free or by free-bound emission from a hot gaseous envelope around the star. This means that the infrared excess must be due to a dust shell. Consequently, we favor the variable obscuration model to explain the large and rapid brightness fluctuations. (We aren't, however, going to rule out starspots as the cause of the smaller fluctuations.)

This patchy-dust explanation also provides a further link to the less massive T Tauri stars because in 1982 our group cited a clumpy dust shell as the cause of the irregular variability of the T Tauri star RY Lupi and this work still stands.

Obviously the Herbig stars have not yet yielded all their secrets, and it is far from clear what mechanism(s) cause them to vary. To understand these stars better, we need detailed coverage of their optical variability and we need to search for any periodicities which might result from the rotation of a spotted star. Since many of the Herbig stars are fairly bright (those in the observing programs I've described are from about eighth to thirteenth magnitude), they fall within the range of many backyard telescopes. The increasing number of amateur observers with sophisticated photoelectric photometers means that regular monitoring of some Herbig stars could be done by amateurs. The results of such a program, combined with detailed spectra and infrared observations by professional workers could provide much useful information and reaffirm the links between these two halves of the astronomical community.

John K. Davies is an astronomer and aerospace engineer. He is currently working at the University of Birmingham (U.K.) where he is helping to develop an extreme ultraviolet space telescope as part of the ROSAT project. Previously, he worked on the IRAS satellite.

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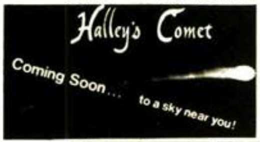
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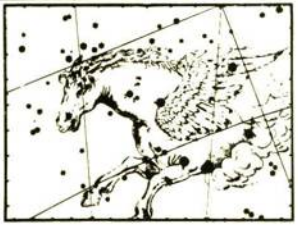

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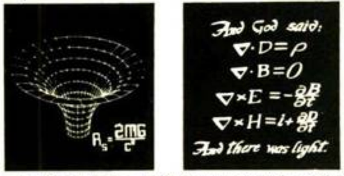
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And there was light.

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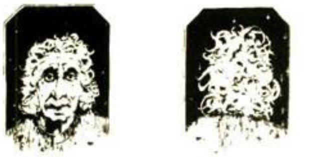
Front: Black hole w/ Schwartzchild's radius.
Back: Maxwell's equations of light.



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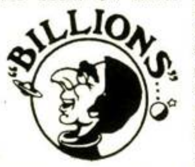

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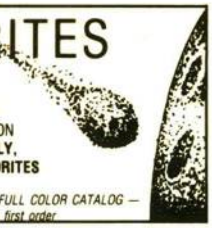

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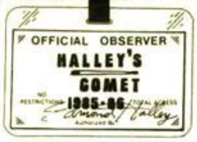

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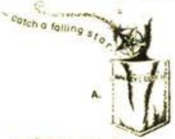

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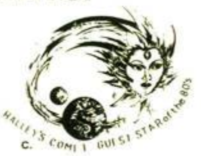
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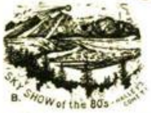
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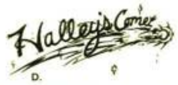

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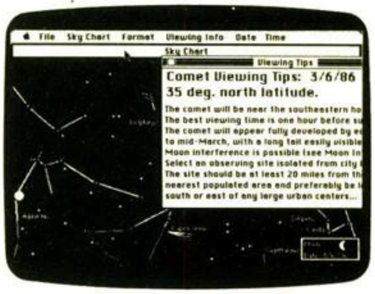

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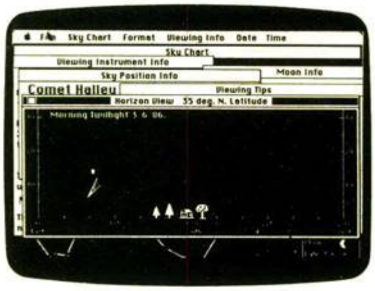

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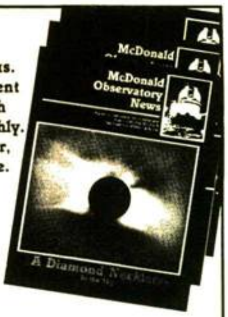

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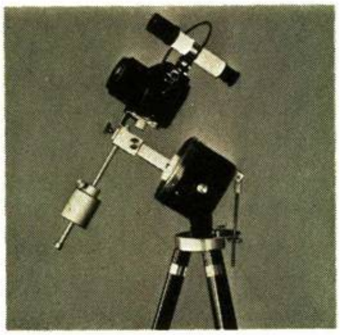

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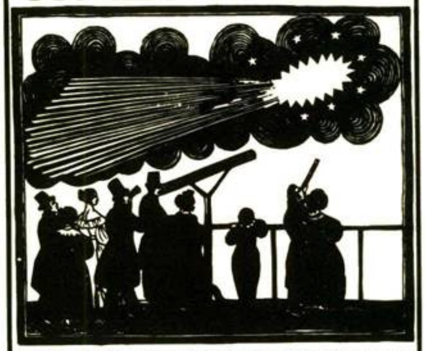

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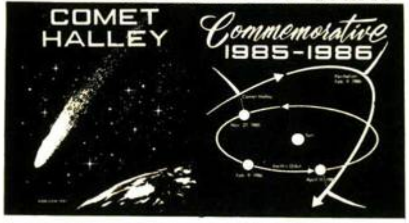

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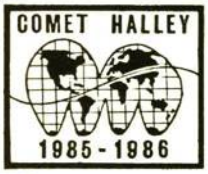

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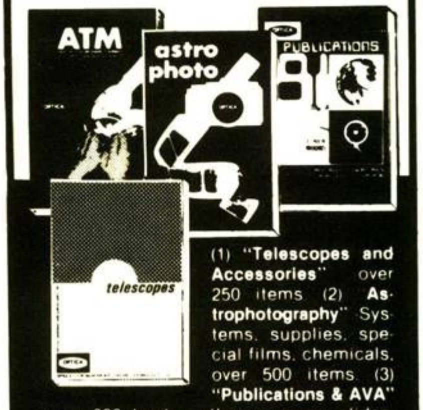

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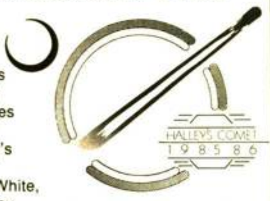

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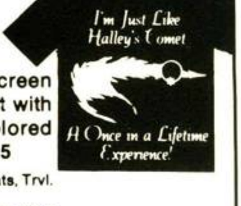
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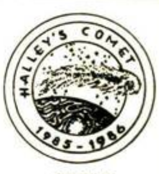

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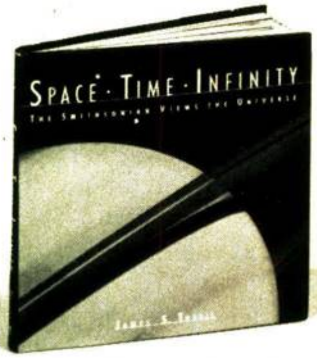

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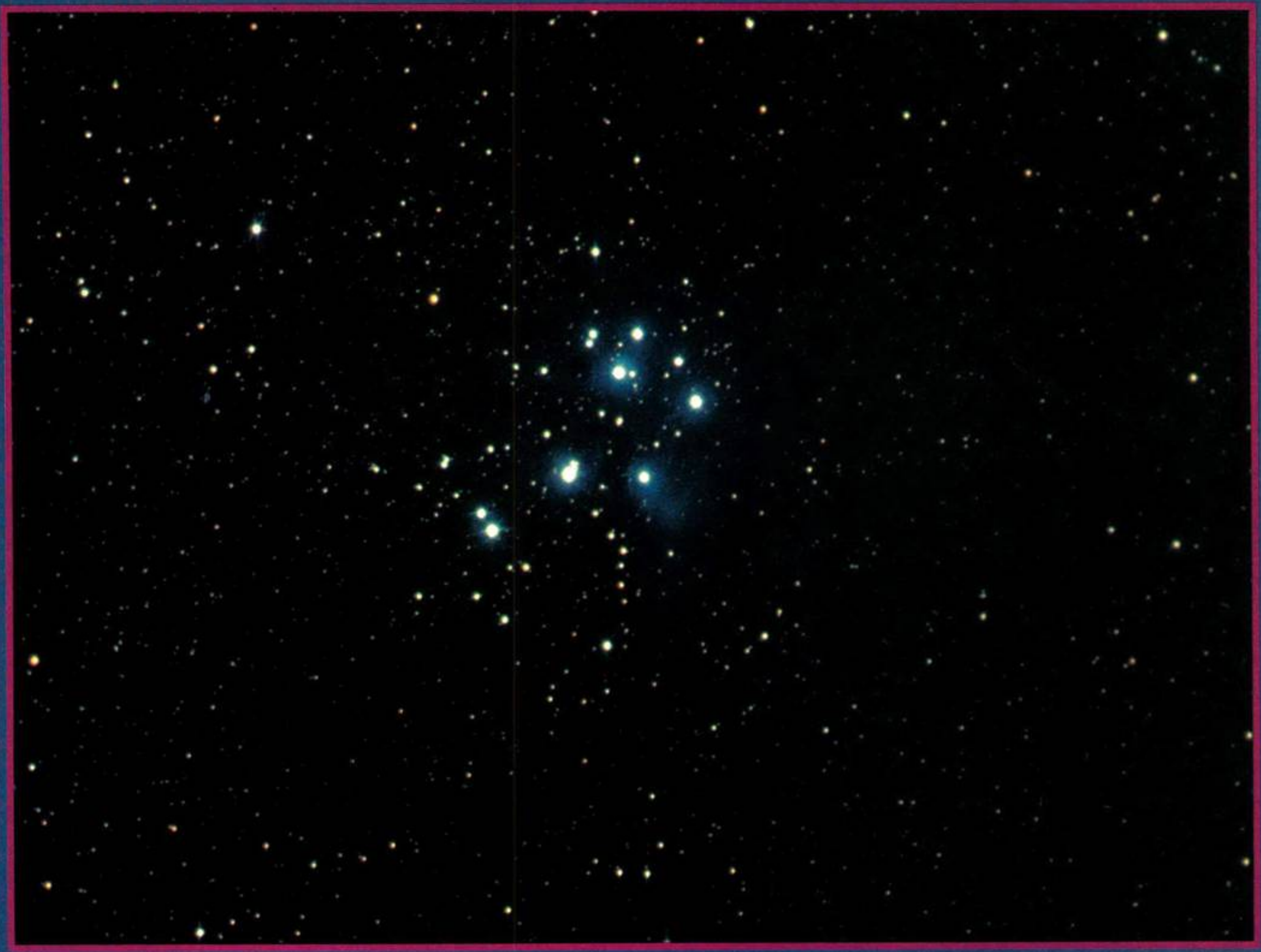
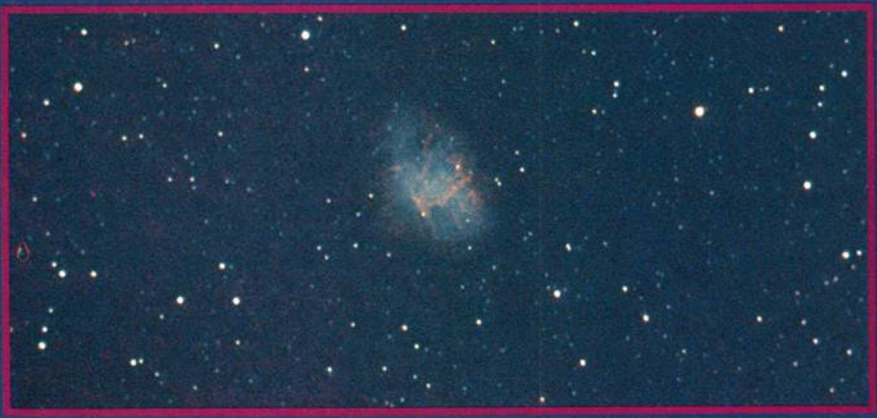
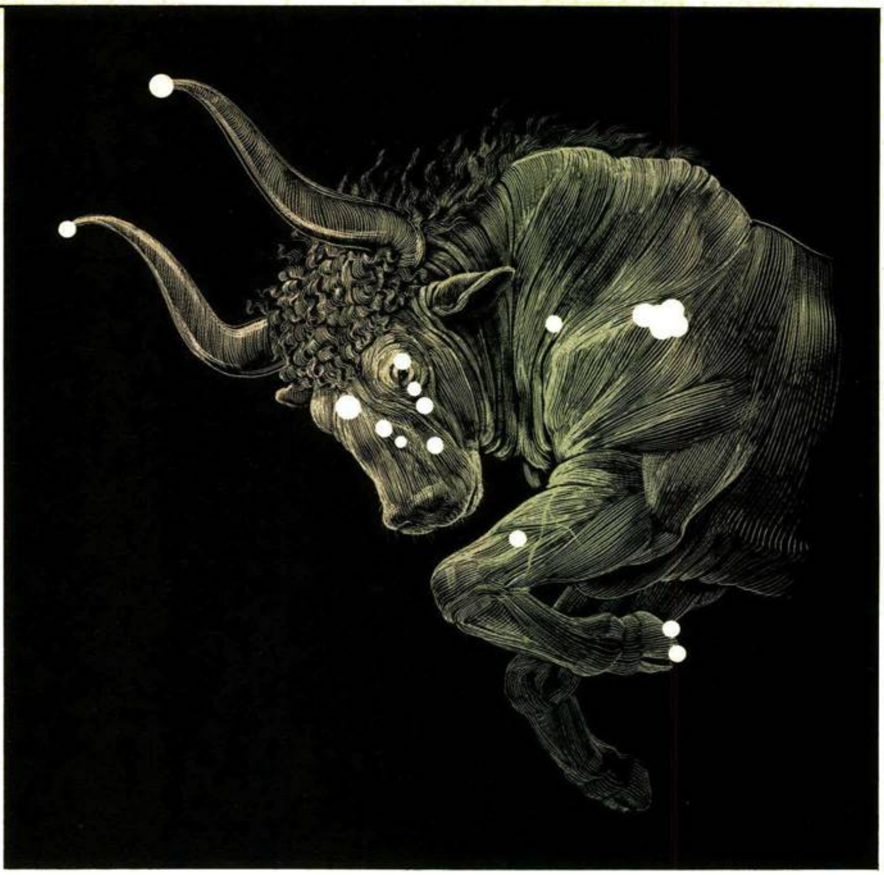




Above: The Pleiades cluster contains dozens of bright blue-white stars visible in binoculars. Large backyard telescopes show its faint reflection nebulosity, principally surrounding the star Merope. Photo by Mace Hooley. Left center: The Crab Nebula, M-1, is the sky's best example of a supernova remnant. Photo by Jack B. Newton. Bottom left: NGC-1647 is a large and scattered cluster of 200 stars. Photo by Lee C. Coombs. Bottom right: NGC-1746, another large cluster in Taurus, contains only 20 stars in an area spanning 42'. Photo by Lee C. Coombs.

Taurus

Tau
Tauri


Keith Ward

Lodged between Orion and Perseus in the bright Milky Way is **Taurus** the Bull, a constellation containing two of the sky's brightest star clusters. Along with these, Taurus also contains many unusual variable stars of all types.

Lying at a distance of about 40 parsecs, **the Hyades** is the second closest cluster to us, the nearest being the Ursa Major Moving Group. The Hyades contains several hundred stars, 132 of which are brighter than ninth magnitude, in an area spanning 5.5° across. The clusters' stars come in many colors and there are several fine double stars within the group, making the Hyades a wonderful area of sky to scan with binoculars.

The bright star in this region, **Aldebaran**, is not a member of the cluster but rather a foreground object. It lies at the paltry distance of only 21 parsecs — about halfway to the center of the Hyades. Aldebaran is not only the 13th brightest star in the sky, but it's also a double star. The primary, a K5 subgiant, shines at magnitude 0.9; 30.4″ away in position angle 112° lies its companion — a dwarf M2 star feebly shining at magnitude 13.4. Because of the great difference in brightness between the two stars, spotting the red dwarf is not always easy.

The most brilliant star actually inside the Hyades cluster is Theta² (θ^2) Tauri, a magnitude 3.3 A7 subgiant. Other bright Hyades stars that form the cluster's distinctive "V" shape include Aldeberan, Gamma (γ) Tauri (magnitude 3.7, type G9 subgiant), Delta (δ) Tauri (magnitude 3.8, K0 subgiant), and Epsilon (ε) Tauri (magnitude 3.5, K0 subgiant).

Because the Hyades cluster is so close to us and contains such a broad range of stars, it is a veritable gold mine in the sky for astrophysicists: using proper motion studies, spectroscopy, photometry, and photography, they have gleaned huge amounts of invaluable data from the Hyades cluster.

About 12° northwest of the Hyades is the brilliant **Pleiades** star cluster (Messier 45). Although not as bright or large as the Hyades — magnitude 1.2 *vs.* 0.5 and just under 2° *vs.* 5.5° in size — the Pleiades also contains hundreds of stars and seems brighter because it is more condensed. The brightest stars in the Pleiades are the so-called Seven Sisters from Greek mythology: Alcyone (Eta [η] Tauri), Atlas (27 Tauri), Electra (17 Tauri), Maia (20 Tauri), Merope (23 Tauri), Taygeta (19 Tauri), and Celaeno (16 Tauri).

The Pleiades is a young cluster containing bluish-white stars; the brightest objects in the group are all B-type subgiants or main sequence stars. Several are Be stars showing peculiar emission lines in their spectra. At a distance of about 120 parsecs, or roughly three times that of the Hyades, the stars are not as easily studied as the Hyades, but they provide a wealth of information for astronomers nonetheless.

Since the Pleiades cluster covers nearly 2° of sky, the best way to observe it is with a pair of binoculars, a rich-field telescope, or even a finderscope. These instruments allow you to see the entire cluster at once, affording a good impression of the dipper shape formed by the brightest members. A large telescope will reveal dozens of additional stars, but you'll be limited to eyeing part of the cluster and scanning around to see the whole thing. On dark nights, a large scope may also show faint reflection nebulosity surrounding several of the stars, particularly Merope. This is extremely faint dust caused to shine by reflected starlight from the Pleiades' members. Some observers describe its delicacy as resembling "breath on a mirror."

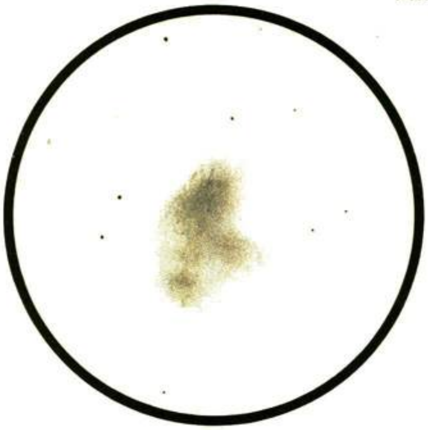
Taurus abounds with other, albeit smaller, star clusters. One of these is **NGC-1647** a group measuring 45′ across and shining with the light of a magnitude 6.4 star. NGC-1647 would normally appear far more prominent, but its proximity to the bright Hyades and Pleiades clusters causes it to be overlooked by many observers. Containing 200 stars, NGC-1647 is a rich cluster that is easily observable in any telescope. Its brightest stars, which shine at eighth magnitude and are bluish-white in color, appear as fainter versions of the Pleiades stars. Accordingly, NGC-1647 lies at a distance of about 500 parsecs — some 4.5 times farther away than the Pleiades.

Another bright cluster is **NGC-1746**, a group similar in size and brightness to NGC-1647. Covering 42′ of sky and shining at magnitude 6.1, this cluster appears as a "washed-out" version of NGC-1647 in the sense that it has only one-tenth as many stars. Yet the 20 stars

For information on naked-eye sky viewing, including planets, constellations, and mythology, see **Eye on the Sky**.

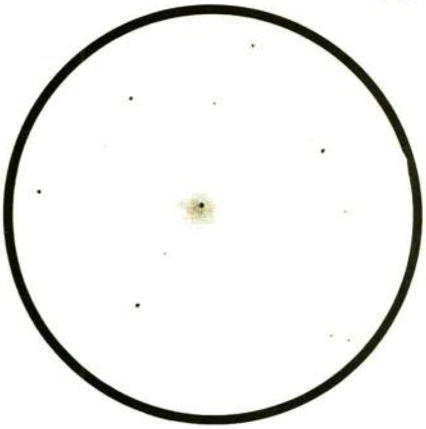
M-1

17.5-inch f/4.5
reflector
71x



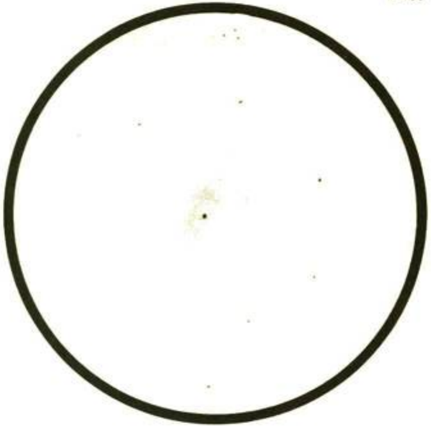
NGC-1514

17.5-inch f/4.5
reflector
71x



NGC-1554/5

17.5-inch f/4.5
reflector
71x



Sketches by David J. Eicher

in NGC-1746 are bright enough to equal the combined magnitude of the 200 stars found in NGC-1647. NGC-1746 lies at a distance of 420 parsecs.

Two smaller clusters found only a few degrees apart are **NGC-1807** and **NGC-1817**. NGC-1807, a seventh-magnitude object, spans 17′ of sky. It contains 20 stars that are eighth magnitude and fainter and presents a fine sight in small telescopes operating at low power. NGC-1817 is slightly fainter and smaller but is also richer, containing three times as many stars. The brightest members of NGC-1817 are 11th-magnitude type A stars. The distance to NGC-1817 is 1.75 kiloparsecs; the distance to NGC-1807 is not well-established.

One of the oddest deep-sky objects in Taurus is the faint, variable reflection nebula **NGC-1554/5**. This low surface brightness object is normally bright enough to spot with a telescope 12 inches or larger. Occasionally this nebula becomes brighter, but normally it appears much like the Pleiades reflection nebulosity — so subtle that the slightest amount of atmospheric haze renders it invisible. NGC-1554/5's variability stems from its illuminating star, **T Tauri** — a young nebular variable enshrouded in a cocoon of warm gas and dust. As the star irregularly varies between magnitudes 9.4 and 13, the nebula gains and loses surface brightness.

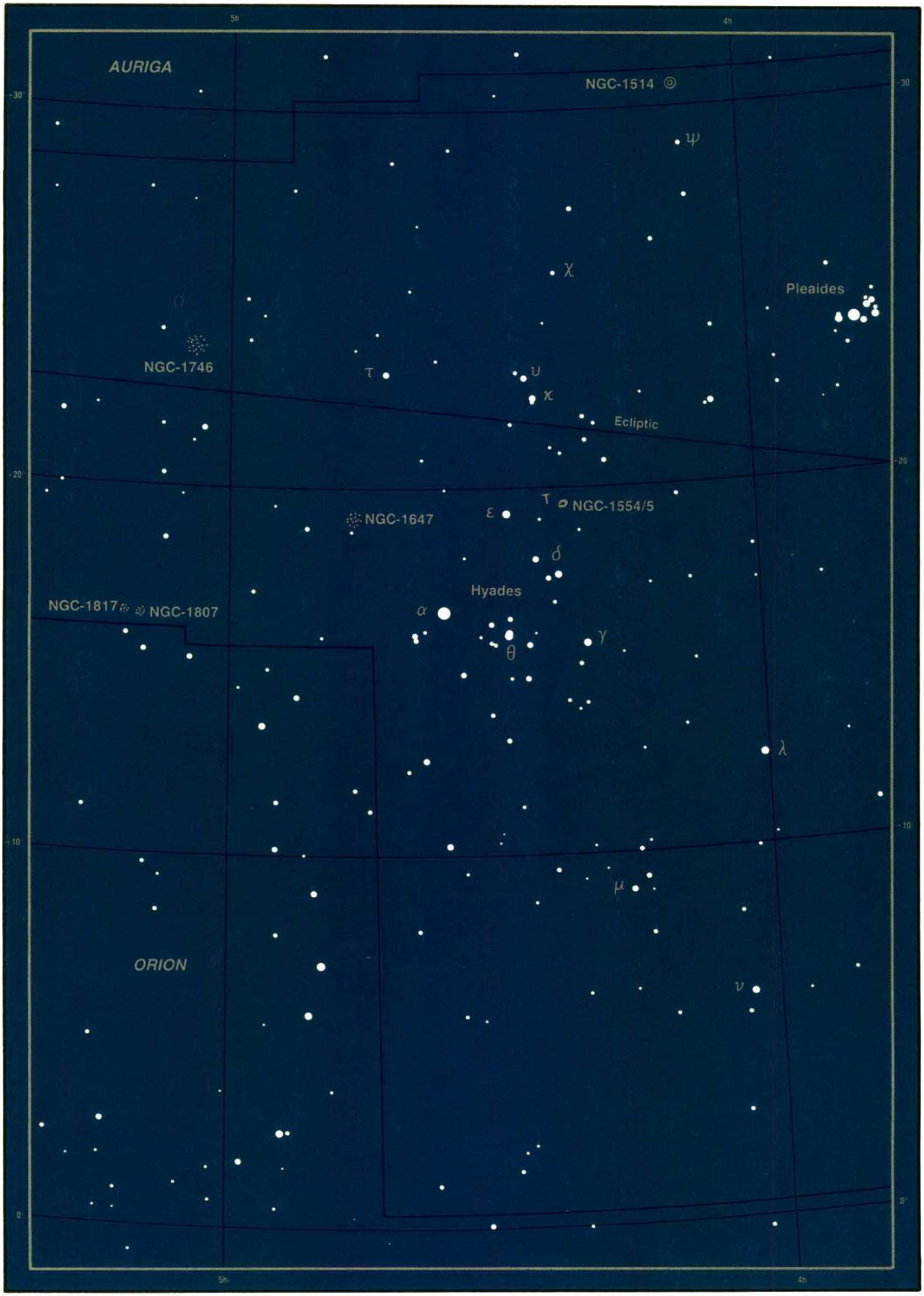
Taurus contains several other unusual variable stars. A bright eclipsing variable is **Lambda (λ) Tauri**. This star varies regularly from magnitude 3.4 to 4.1 every 3.95 days when one of its components passes in front of the other. **RV Tauri**, an odd irregular star, fluctuates between magnitudes 9.5 and 13 over a period of some 79 days. **RR Tauri**, another irregular variable, moves between magnitudes 9.9 and 13 in a completely chaotic fashion. **Zeta (ζ) Tauri** varies quite irregularly from magnitude 2.9 to 3.0 because it is a so-called shell star, a hot young star encapsulated by a warm cloud of gaseous nebulosity.

The lone bright planetary nebula in Taurus is **NGC-1514**, an object that shines at photographic magnitude 10 and covers a semicircular arc some 1.9′ in diameter. NGC-1514's surface brightness is rather low and the nebula surrounds a ninth-magnitude central star. These factors conspire to make observing NGC-1514 difficult with very small instruments.

Taurus contains the sky's best example of a supernova remnant — **M-1**, the Crab Nebula (NGC-1952). The Crab, so named by Lord Rosse for its wispy filamentary structure, is the visible remains of a 1054 A.D. supernova documented by Chinese and Amerindian astronomers. Small telescopes show the Crab Nebula as an 8′ x 6′ oval glow without structure; large backyard instruments show an irregular shape and changing surface brightness over the nebula's face. The Crab's magnitude is about 9, making it visible as a fuzzy spot even in finderscopes under a dark, moonless sky.

Object	M#	Type	R.A. (2000)	Dec.	Mag.	Size/Sep./Per.
Pleiades	M-45	⊙	3h 47.0m	+24°07′	1.2	110′
Lambda (λ)		EV	4h 00.7m	+12°29′	3.4↔4.1	3.95d
NGC-1514		■	4h 09.2m	+30°47′	10p	1.9′
NGC-1554/5		☐R	4h 21.8m	+19°32′	—	var.
T		IV	4h 22.0m	+19°32′	9.4↔13	irr.
Hyades		⊙	4h 27.0m	+16°00′	0.5	330′
Alpha (α)		★^{2}	4h 35.9m	+16°31′	0.9, 13.4	30.4″
NGC-1647		⊙	4h 46.0m	+19°04′	6.4	45′
RV		IV	4h 47.1m	+26°11′	9.5↔13	79d
NGC-1746		⊙	5h 03.6m	+23°49′	6.1p	42′
NGC-1807		⊙	5h 10.7m	+16°32′	7.0	17′
NGC-1817		⊙	5h 12.1m	+16°42′	7.7	16′
NGC-1952	M-1	SNR	5h34.5m	+22°01′	8.5	8′x6′
Zeta (ζ)		★^{s}	5h 37.6m	+21°09′	2.9↔3.0	irr.
RR		IV	5h 39.5m	+26°23′	9.9↔13	irr.

⊙	*Open Star Cluster*
■	*Planetary Nebula*
☐R	*Reflection Nebula*
SNR	*Supernova Remnant*
★^{2}	*Double Star*
★^{s}	*Shell Star*
EV	*Eclipsing Variable*
IV	*Irregular Variable*


5h
4h
AURIGA
30°
NGC-1514
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Pleaides
NGC-1746
τ
υ
κ
Ecliptic
20°
T
NGC-1554/5
ε
NGC-1647
δ
Hyades
NGC-1817
NGC-1807
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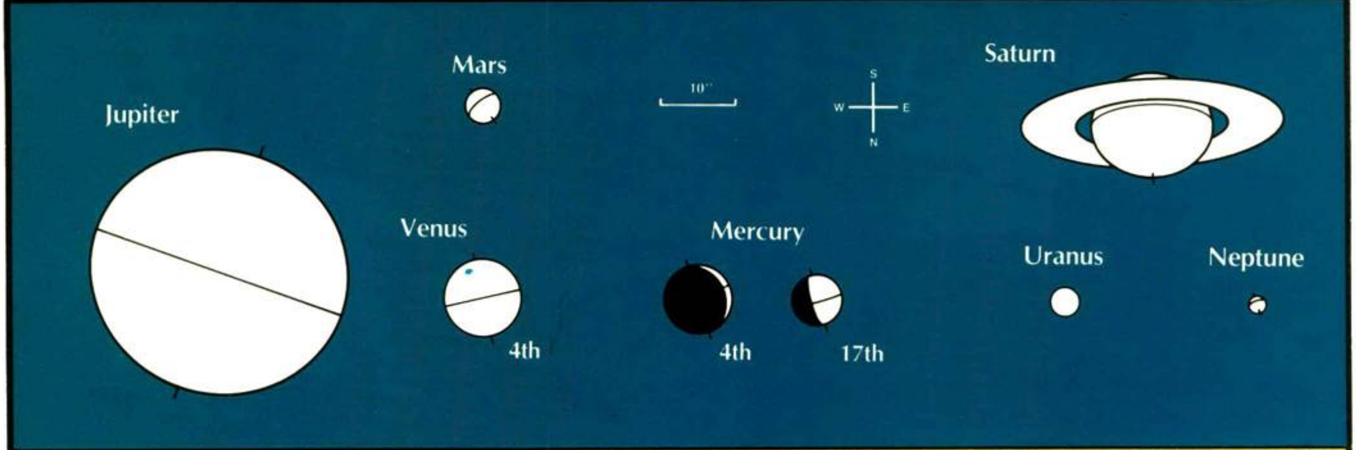
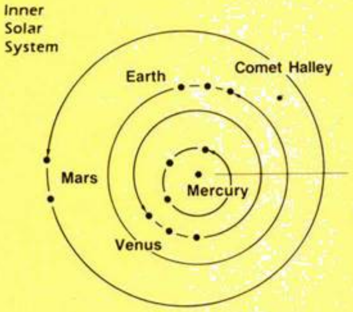
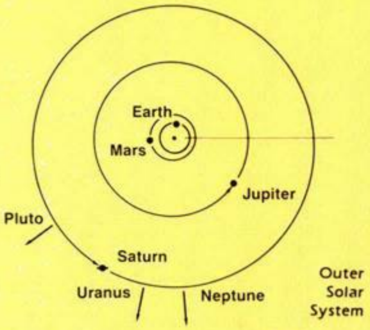
Planetary Data December 1985


Jupiter
Mars
10''
S
W
E
N
Saturn
Venus
4th
Mercury
4th
17th
Uranus
Neptune

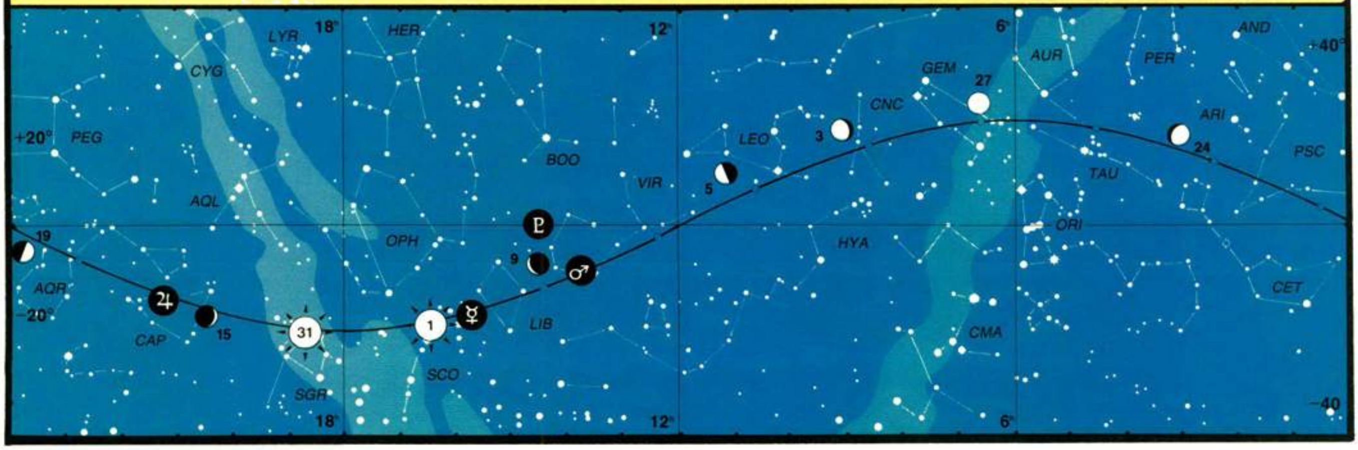
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (2000.0)	Dec.
Sun		1	−26.8	32.5′	—	0.99	—	—	248°44.5′	16h 28.9m	−21°47.5′
		15	−26.8	32.6′	—	0.98	—	—	262°57.7′	17h 30.2m	−23°16.0′
		31	−26.8	32.6′	—	0.98	—	—	279°15.3′	18h 41.1m	−23°06.4′
Mercury	☿	1	3.8	9.8″	2%	0.67	0.31	79°48.4′	244°01.2′	16h 09.4m	−19°20.2′
		15	−0.3	7.0″	57%	0.96	0.36	159°06.5′	242°13.4′	16h 01.8m	−18°10.6′
		31	−0.4	5.3″	87%	1.26	0.44	218°33.3′	261°39.0′	17h 23.7m	−22°46.0′
Venus	♀	1	−3.9	10.1″	98%	1.66	0.72	220°27.2′	237°01.0′	15h 39.6m	−18°38.5′
		15	−3.9	9.9″	99%	1.68	0.73	242°48.3′	254°37.4′	16h 53.4m	−22°12.5′
		31	−3.9	9.8″	100%	1.70	0.73	268°12.2′	274°45.4′	18h 20.7m	−23°39.0′
Mars	♂	10	1.6	4.5″	94%	2.09	1.65	179°30.3′	207°14.6′	13h 42.7m	− 9°26.6′
		20	1.6	4.5″	94%	2.00	1.65	183°57.7′	213°24.9′	14h 06.2m	−11°38.0′
Jupiter	♃	15	−2.1	35.1″	99%	5.59	5.04	323°39.8′	315°02.5′	21h 10.9m	−17°06.4′
Saturn	♄	15	0.5	15.2″	100%	10.89	9.97	241°23.7′	243°29.5′	16h 07.3m	−19°05.4′
Uranus	⛢	15	5.7	3.5″	100%	20.10	19.12	258°15.8′	258°40.2′	17h 10.7m	−23°00.9′
Neptune	♆	15	8.0	2.2″	100%	31.22	30.25	273°16.7′	273°09.6′	18h 13.6m	−22°20.5′
Pluto	♇	15	13.8	0.1″	100%	30.38	29.74	215°01.9′	216°35.0′	14h 38.4m	1°37.9′


Inner
Solar
System
Earth
Comet Halley
Mars
Mercury
Venus


Earth
Mars
Jupiter
Pluto
Saturn
Uranus
Neptune
Outer
Solar
System

Moon Data

Last Quarter. . . . . December 5 at 9h01m
New Moon. . . . . December 12 at 0h54m
First Quarter. . . . . . . December 19 at 1h58m
Full Moon. . . . . December 27 at 7h30m
Last Quarter. . . . . January 3 at 19h47m
New Moon. . . . . January 10 at 12h22m
Perigee: Dec. 11 at 0h43m. . . . . 358,682 km
Apogee: Dec. 23 at 7h16m. . . . 405,602 km


18°
12°
6°
18°
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+20°
−20°
+40°
−40
LYR
HER
CYG
PEG
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BOO
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CNC
GEM
AUR
PER
AND
ARI
PSC
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ORI
HYA
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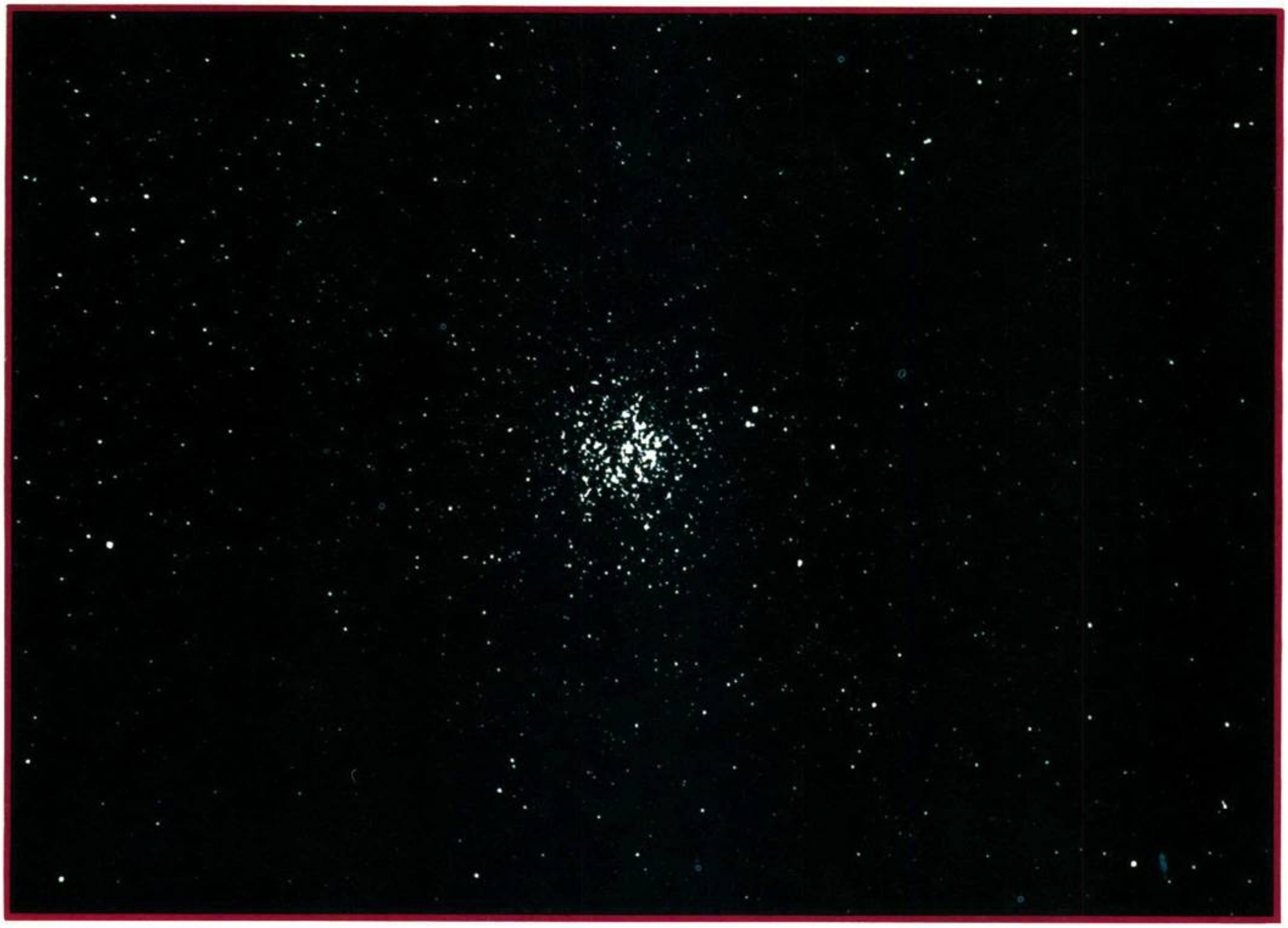


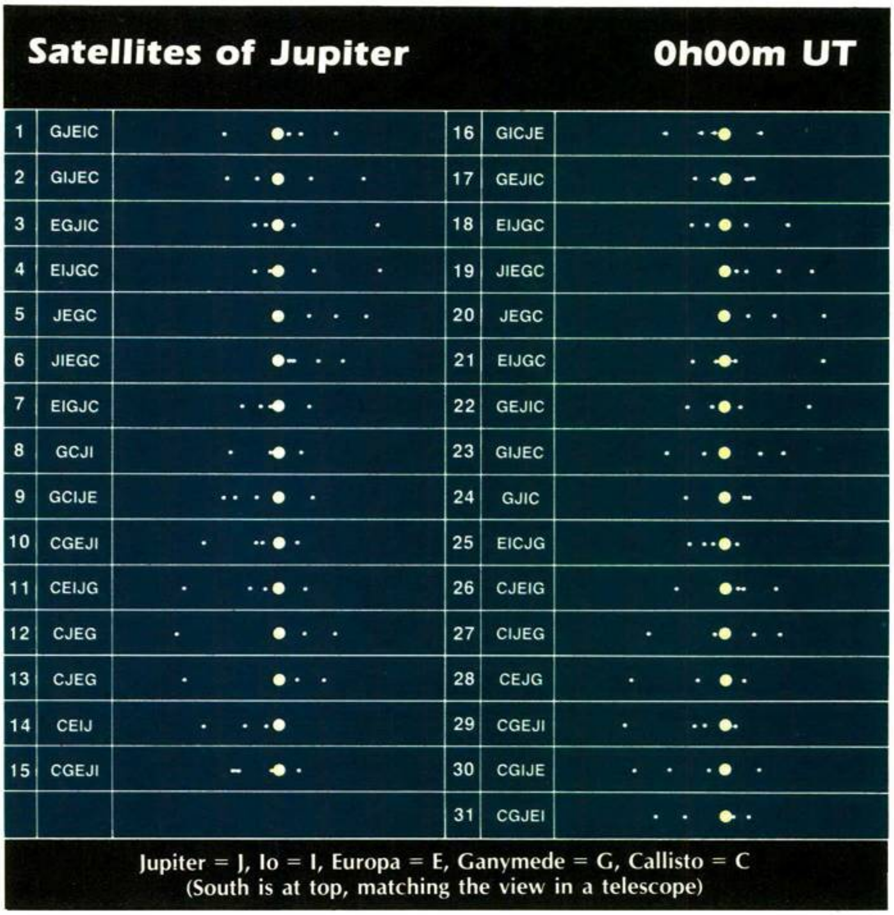
M-11 in the Milky Way constellation of Scutum ranks high on many "favorite star cluster" lists. Howard McCallon photographed the cluster using a 12.5-inch Newtonian and a 5-minute exposure at f/5.6 on 103a-O film.

Mercury

From the beginning of December until the second week in January, Mercury will be visible in the morning sky before sunrise. This is one of the year's best apparitions for the planet, and telescope owners shouldn't miss the chance to observe this elusive celestial object.

Maximum elevation (10°, 45 minutes before sunrise) occurs on December 15th, but the planet will be at least 5° high from the 6th to 31st. Greatest western elongation from the Sun occurs on the 17th.

Besides being generally visible, Mercury also has two conjunctions worth getting up for. Around 4h UT on the 4th, Mercury will pass a degree and a half north of Venus; of the two, Venus is by far the brighter (−3.9 magnitude vs. 1.9). About two weeks later at 17h UT on the 16th, Mercury will pass half a degree north of Saturn. Mercury will be at −0.3 magnitude, Saturn 0.5, and both objects will be low in the sky. To get a good view of either conjunction, you'll need an observing site with a very low east-southeastern horizon. In addition, poor



Satellites of Jupiter **0h00m UT**

1	GJEIC	16	GICJE
2	GIJEC	17	GEJIC
3	EGJIC	18	EIJGC
4	EIJGC	19	JIEGC
5	JEGC	20	JEGC
6	JIEGC	21	EIJGC
7	EIGJC	22	GEJIC
8	GCJI	23	GIJEC
9	GCIJE	24	GJIC
10	CGEJI	25	EICJG
11	CEIJG	26	CJEIG
12	CJEG	27	CIJEG
13	CJEG	28	CEJG
14	CEIJ	29	CGEJI
15	CGEJI	30	CGIJE
		31	CGJEI

Jupiter = J, Io = I, Europa = E, Ganymede = G, Callisto = C
(South is at top, matching the view in a telescope)

Right: Orion blazes brightly in this shot that wins Tim Pickering December's "Best Astrophoto" award. Pickering used a 12-minute exposure at f/1.4 with a 50mm lens. Left: Jupiter on August 23, 1985. Photo taken by Daniel Falbe with an 8-inch SCT and a ½-second exposure at f/138 on Ektachrome 400.

seeing — a natural result of observing so close to the horizon — means you'll view things best with low magnifications.

Venus

Venus has all but disappeared into the solar glare in the morning sky. How long can you keep it in view after its conjunction with Mercury?

Earth

The solstice occurs on December 21st at 22h08m UT. This is the instant when the Sun reaches its southern-most point on the celestial sphere and winter begins in the northern hemisphere.

Mars

On the morning of December 8th, the waning crescent Moon will either pass near or occult Mars, depending on where you are observing from. Generally, the occultation is visible over the Appalachians and the Piedmont region south of central Pennsylvania and New Jersey. (Mars will emerge from behind the Moon's dark limb at around 9h02m UT to 9h20m — again, depending on observing location.) North and west of this region, you'll have to settle for a conjunction with the Moon passing near the planet.

In a stellar occultation, the star "blinks" on or off virtually instantaneously. But planets have perceptible disks, so when the Moon covers or uncovers a planet, the event lasts several seconds. Astrophotographers who are alert and prepared can often grab two or more photos showing partial stages of immersion or (in this case) emersion. Good luck!

Minor Planets

1 Ceres (magnitude 7.4) has a direct (eastward) motion in the hindquarters of Leo. Its positions:

1st: 10h 59m 00s, 16° 48.7′
10th: 11h 08m 14s, 16° 41.3′
20th: 11h 16m 50s, 16° 46.9′
30th: 11h 23m 25s, 17° 08.8′

Ceres rises around 11:30 p.m. local time on the 15th.

2 Pallas (7.6) moves westward from southern Canis Minor into northern Columba this month; opposition occurs on December 22nd. Its positions:

1st: 6h 19m 02s, −31° 24.1′
10th: 6h 13m 01s, −32° 34.5′
20th: 6h 04m 43s, −33° 05.6′
30th: 5h 55m 57s, −32° 41.6′

Pallas rises about 9:30 p.m. local time on the 15th.

3 Juno (11.5) lies in north-central Libra. Its positions:

1st: 15h 16m 49s, − 9° 40.3
10th: 15h 28m 38s, −10° 11.3′
20th: 15h 41m 34s, −10° 39.4′
30th: 15h 54m 09s, −11° 00.2′

Juno rises around 5:00 a.m. local time on the 15th.

18 Melpomene (9.9) lies near the junction of Canis Minor and Monoceros. Its positions:

1st: 7h 21m 24s, 7° 21.3′
10th: 7h 15m 55s, 7° 24.9′
20th: 7h 07m 15s, 7° 49.3′
30th: 6h 56m 46s, 8° 35.6′

Melpomene rises about 8:00 p.m. local time on the 15th.

To locate a minor planet, plot its positions lightly in pencil on a good star atlas (*Sky Atlas 2000.0*, for example) and sketch a smooth curve linking the points. Then observe the starfield at low magnification and photograph or plot by hand what you see. Check the field a night or two later; the faint "star" that has moved is it. (All minor planet coordinates are for the epoch 2000.0.)

Jupiter

The sole bright planet in the evening sky, Jupiter makes a fine sight in any telescope. Binoculars with 6x will show you its moons, a small telescope will display its disk and a few cloud belts, and a large telescope will add many more details and perhaps a hint of color to the cloud belts.

Among the jovian moons, three events are worth looking for. On the 25th between 2h34m and 2h41m UT, Callisto will partially occult Io; you'll see a 1.0 magnitude drop in brightness as the event occurs. Between 0h29m and 0h34m UT on the 26th, Io will partially occult Europa with a 0.6 magnitude dimming. Lastly, on the 29th at 0h08m UT, Ganymede will partially eclipse Europa and a 0.7 magnitude dimming results. Observing these events calls for good seeing, a sturdily-mounted telescope, and medium to high magnification.

Saturn

All but invisible in morning twilight at the beginning of December, Saturn won't be an easy telescopic target until the last week of the month. Even then, low elevation and poor seeing will produce less than optimal views. (Look for Saturn's conjunction with Mercury, however — see above.)

Uranus

Uranus is in conjunction with the Sun on December 10th and is out of sight all month.

Neptune

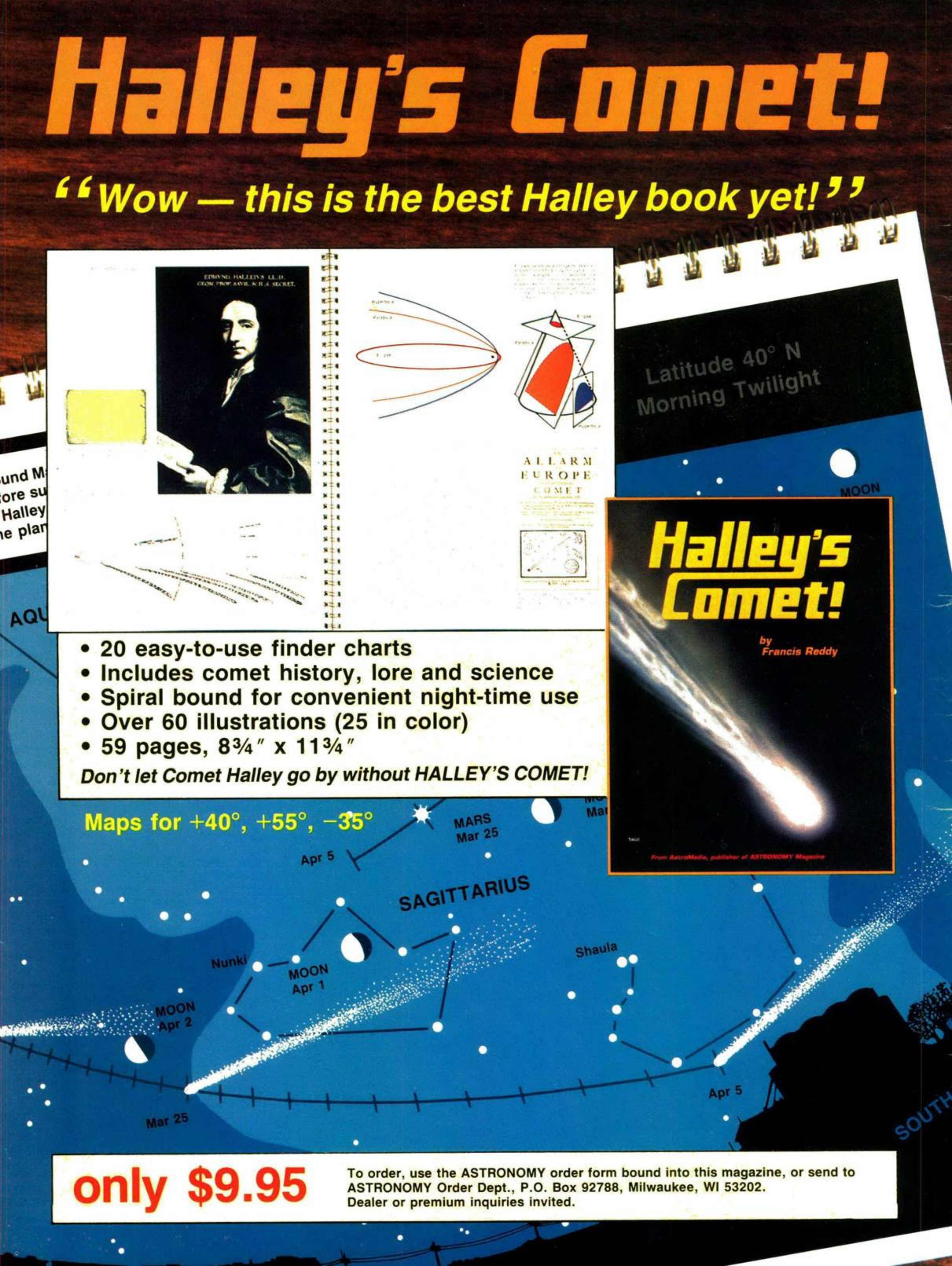
Like Uranus, Neptune also passes through solar conjunction this month (the 25th) and will be out of view until well into January.

Comet Halley

See Gazer's Gazette beginning on page 30 for a finder chart showing the comet's path.

Halley's Comet!

"Wow — this is the best Halley book yet!"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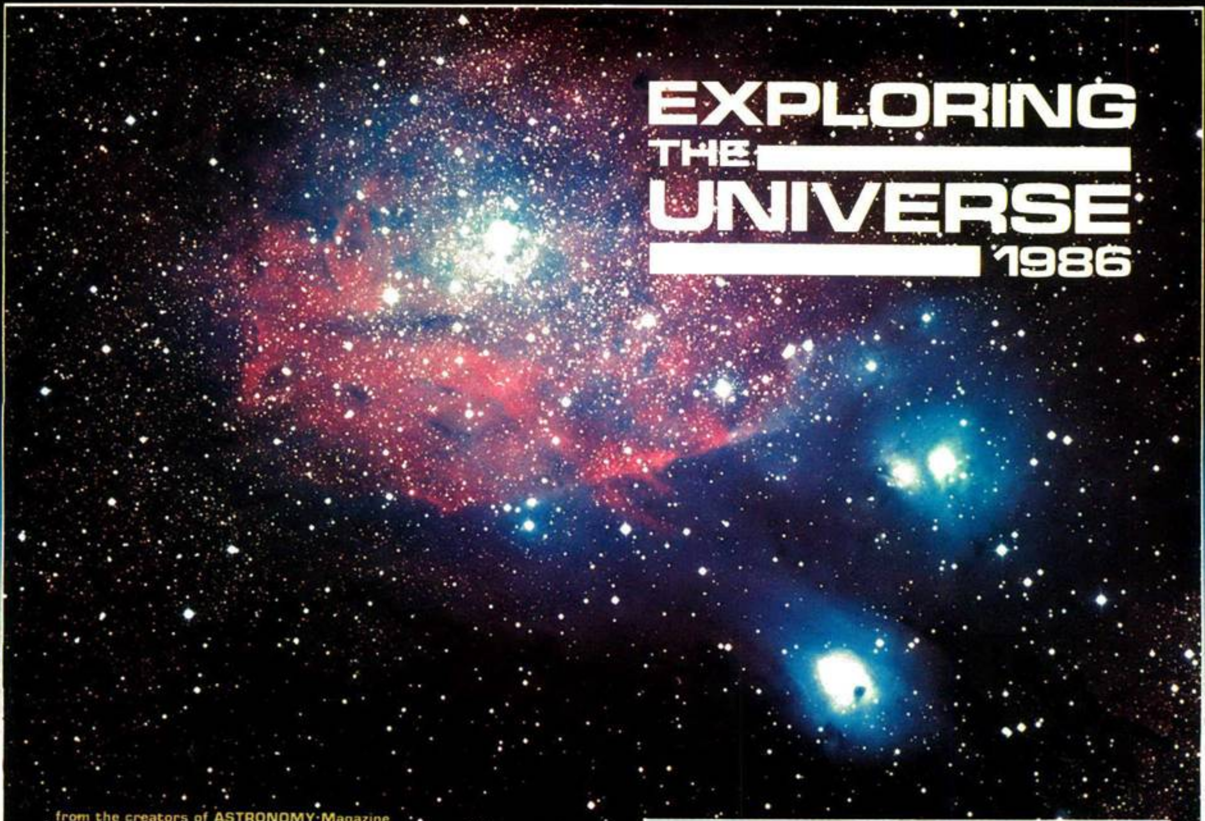
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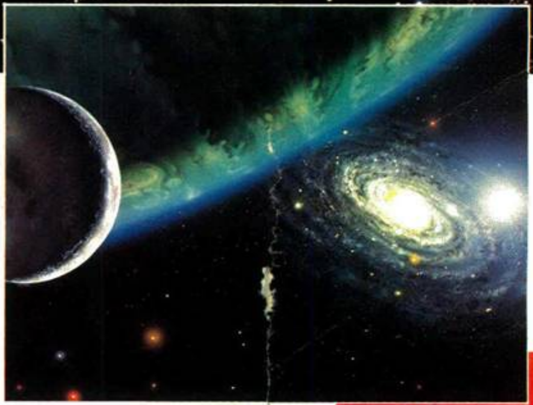

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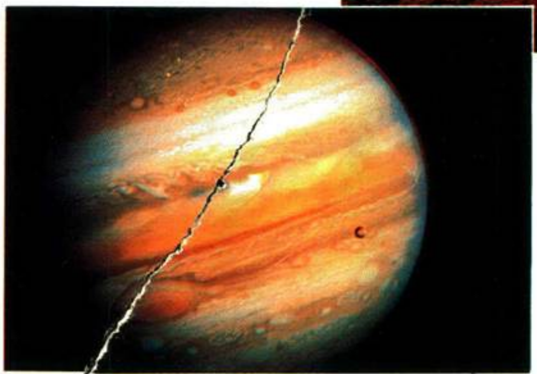

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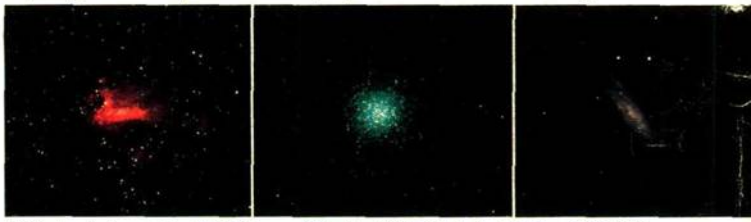

C8 Astrophotographs: M-17, Omega Nebula; M-13, Globular Cluster; NGC-253.

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